IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. National Stage Appln. of	)	
	)	
Lutz Axel MAY	)	Art Unit: Unassigned
	)	
Serial No.: 10/529,326	)	Examiner: Unassigned
	)	
Filing Date: March 25, 2005	)	Confirmation No.: 8656
	)	
I.A. No. PCT/EP03/10634	)	Attorney Docket No. 119508-00282
	)	
I.A. Filing Date: September 24, 2003	)	
	)	
Priority Date: September 25, 2002	)	
	)	
For: TORQUE SIGNAL TRANSMISSION	)	

RENEWED PETITION UNDER 37 C.F.R. § 1.47(b)

Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The owner of the above-cited patent application, Abas, Inc., a wholly-owned subsidiary of Methode Electronics, Inc., (hereinafter "Rule 1.47(b) applicant") respectfully requests reconsideration of the dismissal of its previously submitted original Petition Under 37 C.F.R. §1.47(b), which requested that the above-captioned patent application be accepted without the signature of the inventor, Lutz Axel May. The Rule 1.47(b) applicant requests reconsideration on the merits of the following:

- This renewed Petition, including the Exhibits submitted herewith;
- A Decision on Petition Under 37 C.F.R. § 1.47(b) issued by the U.S. Patent & Trademark Office (PTO) on July 28, 2006, in connection with U.S. Patent Application Ser. No. 10/482,002, also owned by Abas, Inc.; and
- The Rule 1.47(b) applicant's original Petition and referenced enclosures, exhibits, and other papers submitted therewith.

This renewed Petition contains additional information not contained in the previously-submitted Petition.

A. Background

The Decision on Petition dated June 23, 2006, states that six items must be satisfied before a Petition Under 37 C.F.R. §1.47(b) may be granted. With regard to the original Petition, the Patent Office found that items (1), (3), (4), and (6) have been satisfied, but that items (2) (i.e., "Factual proof that the inventor refuses to execute the application or cannot be reached after diligent effort") and (5) (i.e., "Proof of proprietary interest in the application"), have not been satisfied. Before specifically addressing items (2) and (5), the following information about another Petition Under 37 C.F.R. § 1.47(b) submitted to the Patent Office in connection with another matter is provided.

B. Previously Granted Decision on Petition

The Rule 1.47(b) applicant wishes to point out that it has submitted to the U.S. Patent & Trademark Office (PTO) a Petition Under 37 C.F.R. § 1.47(b) in connection with several pending patent applications, all of which name Lutz May as the inventor or a joint inventor. Some of those petitions have been granted; others are in various stages of being reviewed by the PTO or have been denied by the PTO.

The original Petition Under 37 C.F.R. § 1.47(b) submitted to the PTO in connection with U.S. Patent Application Ser. No. 10/482,002 ("the '002 application") was the first Petition that was submitted to the PTO in connection with the aforementioned pending patent applications. After submitted a Second Renewed Petition Under 37 C.F.R. § 1.47(b) to the PTO in connection with the '002 application, the PTO issued a Decision on Petition Under 37 C.F.R. § 1.47(b) on July 28, 2006, which indicates that the Petition has been "GRANTED." That decision was made based upon facts and evidence that are being submitted to the PTO in connection with the present Petition Under 37 C.F.R. § 1.47(b). Exhibit 1 contains a Declaration attesting to the contents of the Second Renewed Petition Under 37 C.F.R. § 1.47(b) that was submitted in connection with the '002 application. Exhibit 2 contains a copy of the aforementioned Decision on Petition.

Accordingly, because the material facts and evidence submitted to the PTO in connection with the '002 application are also being or have been submitted to the PTO in

connection with the present Petition, the Rule 1.47(b) applicant respectfully requests that the Petition Examiner reviewing this Petition grant this Petition for the same reasons that the Petition Examiner granted the Second Renewed Petition in connection with the '002 application.

The Rule 1.47(b) applicant wishes to point out that facts concerning related litigation in Germany (discussed below) were not available to the Petition Examiner that reviewed and granted the Second Renewed Petition in connection with the '002 application. Information concerning the German litigation was submitted to the Patent Office on September 13, 2006, in connection with the '002 application, which is after the July 28, 2006, date of Decision as noted above.

C. Item (2): Factual Proof That The Inventor Refuses To Execute The Application Or Cannot Be Reached After Diligent Effort

In the Rule 1.47(b) applicant's original Petition, a Declaration of Alexander Straus was provided that indicated that Lutz May had been contacted on several occasions and requested to execute the application papers in connection with this and other patent applications. Enclosed herewith (Exhibit 3) is a certified English translation of the various letters and delivery certificates concerning the aforementioned contacts with Lutz May. In particular, two letters, both dated August 24, 2005, from Alexander Straus to Lutz May's attorney are provided in which is indicated that Dr. Straus forwarded the application papers and Declaration/Power of Attorney form to Lutz May. Also included is a Courier Ticket showing that the letters were delivered on August 24, 2005, and a confirmation letter from Eurokurier, dated August 31, 2005, which is the company that provided the courier service for Dr. Straus.

Although the letter to Lutz May's attorney does not specifically mention that the application papers related to the present application were sent to Lutz May, on information and belief the application papers were in fact sent to Lutz May's attorney on August 24, 2005. Enclosed herewith is an electronic mail message from the undersigned to Dr. Straus containing the application papers as an attachment (Exhibit 4; non-relevant portions have been redacted), a copy of the application papers attached to the message (Exhibit 5), and a letter from Alexander Straus confirming that the attachment was sent to Lutz May on August 24, 2005 (Exhibit 6).

Action by the Patent Office is necessary to preserve the rights of Abas, Inc., in the subject patent application. It would be unfair to Abas, Inc., to deny this Petition based solely on the lack of an express refusal from Lutz May to execute the application papers, when in fact it has been Lutz May's tactic to delay and avoid executing the application papers as long as possible, thereby forcing Abas, Inc., to instigate the aforementioned legal action in Germany, at a significant expense to Abas, Inc., all of which has caused, among other things, the unnecessary delay in prosecuting this and other patent applications in the Patent Office (this application, for example, was originally filed in the Patent Office on March 25, 2005, based on an international patent application dated September 24, 2003).

For those reasons, the Rule 1.47(b) applicant respectfully submits that factual proof exists that a *bona fide* attempt was made to present the application papers to Lutz May for his review and signature, and that he refuses to execute those papers.

D. Item (5): Proof Of Proprietary Interest In The Application

As to item (5), M.P.E.P. § 409.03(f) states that proof of a proprietary interest in the subject patent application may be demonstrated by a legal memorandum to the effect that a court of competent jurisdiction would, by the weight of authority in that jurisdiction, award title of the invention that is disclosed in the patent application to Abas, Inc. M.P.E.P. § 409.03(f) also states that the facts in support of any conclusion that a court would award title to Abas, Inc., should be made of record by way of an affidavit or declaration of a person or persons having firsthand knowledge of the same. Also according to M.P.E.P. § 409.03(f), the legal memorandum should be prepared and signed by an attorney at law familiar with the law of the jurisdiction involved and that a copy (in the English language) of a statute (if other than a United States statute) or a court decision (if other than a reported decision of a U.S. federal court or a decision reported in the United States Patents Quarterly) relied on to demonstrate a proprietary interest should also be made of record.

Submitted concurrently herewith is a legal memorandum prepared by Klaus Gennen, Methode Electronics, Inc.'s German counsel, that establishes Abas, Inc.'s proprietary interest in the subject patent application (Exhibit 7). Accordingly, based on the information provided in this renewed Petition and the Klaus Gennen legal memorandum, the Rule 1.47(b) applicant respectfully submits that factual proof exists that Abas, Inc., has a proprietary interest in the present application.

The memorandum of law does not unequivocally state that a court of competent jurisdiction would award title to Abas (as opposed to Methode). The statement was made in the memorandum of law because it was not known at the time the memorandum was prepared whether the relief being sought in related litigation against Lutz May in Germany would request award of title in the present invention and patent application to Abas or to MDI. The Rule 1.47(b) applicant wishes to inform the Patent Office that the relief being sought in the German litigation includes a plea that the German court determine that the disputed catalogue of intellectual property assets (including the present invention) actually belonged to Fast at the time of its insolvency. If that relief is granted, it would effectively be an award of title to Abas (not MDI).

The Rule 1.47(b) applicant also wishes to point out that the aforementioned German litigation against Lutz May is still pending. Between the submission of the previously-submitted original Petition to the PTO on October 28, 2005, in connection with the present patent application, and the submission of this Renewed Petition being filed on this date, the German court hearing the case issued its decision. Thus, that information was not available at the time the original Petition was submitted to the PTO.

In the German litigation, the German court denied Abas, Inc.'s relief and, on information and belief, granted at least some of the claims of defendant Lutz May, citing recent decisions by the Superior Court Duesseldorf (SCD) and the German Supreme Court (GSC). The applicable law at issue was the German Civil Code ("BGB"), which relates to, *inter alia*, employee inventions. The relief that the German court granted Lutz May included a denial that some of his inventions, including the present invention, belonged to Fast Technology at the time of Fast's insolvency. The decision is being appealed by Abas, Inc., on the basis that the German court improperly applied the facts of the case in view of the holdings of the aforementioned recent higher German court decisions. At this time, briefing papers have been submitted to the appeals court, but no oral proceedings have been completed and a decision by the appeals court has not issued.

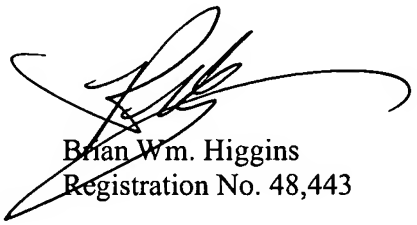
E. Conclusion

In the event there are any questions relating to this renewed Petition or the other papers submitted concurrently herewith, it would be appreciated if the Patent Office would

telephone the undersigned attorney concerning such questions so that the prosecution of this application may be expedited.

Any fee due is authorized above. Please charge any shortage or credit any overpayment of fees to BLANK ROME LLP, Deposit Account No. 23-2185 (119508-00282).

Respectfully submitted,



Brian Wm. Higgins
Registration No. 48,443

BLANK ROME LLP
600 New Hampshire Ave., N.W.
Washington, D.C. 20037
Telephone: (202) 772-5800
Customer No. 27557

Date: December 26, 2006

EXHIBIT 1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. National Stage Appln. of	)	
	)	
Lutz Axel MAY	)	Art Unit: Unassigned
	)	
Serial No.: 10/529,326	)	Examiner: Unassigned
	)	
Filing Date: March 25, 2005	)	Confirmation No.: 8656
	)	
I.A. No. PCT/EP03/10634	)	Attorney Docket No. 119508-00282
	)	
I.A. Filing Date: September 24, 2003	)	
	)	
Priority Date: September 25, 2002	)	
	)	
For: TORQUE SIGNAL TRANSMISSION	)	

DECLARATION OF BRIAN HIGGINS

I, Brian Wm. Higgins, hereby declare:

1. I am an Associate at Blank Rome, LLP, counsel for Abas, Inc., a wholly-owned subsidiary of Methode Electronics, Inc. (hereinafter the "Rule 1.47(b) applicant").

2. I am providing this Declaration in support of the Rule 1.47(b) applicant's Petition Under Rule 1.47(b) that is being submitted to the U.S. Patent & Trademark Office (PTO) in connection with the above-captioned patent application.

3. Unless otherwise stated as being based on information and belief, the facts stated in this Declaration are based on my personal knowledge.

4. U.S. Patent Application Ser. No. 10/482,002 ("the '002 application") identifies Lutz May as the inventor. Lutz May refused to execute the application papers for the '002 application when they were presented to him. After submitting an original and First Renewed Petition Under Rule 1.47(b) to the PTO in connection with the '002 application, the Rule 1.47(b) applicant submitted a Second Renewed Petition Under Rule 1.47(b) to the PTO on April 27, 2006.

5. Attached as Exhibit 2 to the Rule 1.47(b) applicant's Petition is a true and correct copy of a document entitled "Decision on Petition Under 37 C.F.R. § 1.47(b)" that was issued by the PTO on July 28, 2006, in connection with the '002 application, and is signed by Anthony Smith, Attorney Advisor in the Office of PCT Legal Administration. The Decision on Petition was issued in response to the aforementioned Second Renewed Petition Under Rule 1.47(b).

6. In the present application, a Renewed Petition Under Rule 1.47(b) is being submitted to the PTO which, when combined with information in the Rule 1.47(b) applicant's original Petition, contains essentially the same material facts and evidence submitted with the Second Renewed Petition Under Rule 1.47(b) submitted to the PTO on April 27, 2006, in connection with the '002 application, along with additional facts and evidence.

I declare under penalty of perjury that the foregoing is true and correct.

Dated: December 20, 2006

Brian Wm. Higgins
Reg. No. 48,443

EXHIBIT 2

RALPH
MCELROY TRANSLATION
COMPANY

December 22, 2005

Re: 6591-106221 rev 12.21

To Whom It May Concern:

This is to certify that a professional translator on our staff who is skilled in the German language translated the enclosed "6591-106211.rev 12.22.doc" from German into English.

We certify that the English translation conforms essentially to the original German.

Kim Vitray
Operations Manager

Subscribed and sworn to before me this 22nd day of December, 2005.

TINA WUELFING
Notary Public
State of Texas
My Commission Expires
December 8, 2007

Tina Wuelfing
Notary Public

910 WEST AVE.
AUSTIN, TEXAS 78701
www.mcelroytranslation.com

(512) 472-6753
1-800-531-9977
FAX (512) 472-4591

[Letterhead of Becker Kurig Straus, Patent Attorneys]
By courier
Lutz Axel May
c/o NCTE
Engineering GmbH
Erlenhof-Park
Inselkammerstr. 10
82008 Unterhaching
Germany

August 24, 2005
(AS/SL)

US 10/482,002
Our ref.: Case 51856

Dear Mr. May,

As you know, our client is pursuing in the USA the patent granting process for the application named in the subject line, for which the signing of the "Assignments" and the "Declaration for Patent Application and Power of Attorney," respectively, would be necessary.

The contested process concerning this matter in Germany is also known to you.

In order to give you the opportunity to be able to properly sign the "Assignment" formally, herewith we are handing over to you as an attachment to this letter on the protective rights US 10/482,002 an "Assignment," a combined "Declaration for Patent Application and Power of Attorney," and also copies of the relevant documents of the corresponding file portions (submitted application text, file history, state of the art) for your review and for your information.

Herewith, we request that you sign the enclosed "Assignment" and also the combined "Declaration for Patent Application and Power of Attorney" in a legally binding way and to return them to us at the latest by
August 30, 2005.

Sincerely,
Becker Kurig Straus
[signature]

Dr. Alexander Straus

Attachments
as mentioned above
cc: Copy of the letter (without attachments) to Peters Schönberger & Partners

[Letterhead of Becker Kurig Straus]
By courier
Lutz Axel May
c/o NCTE
Engineering GmbH
Erlenhof-Park
Inselkammerstr. 10
82008 Unterhaching
Germany

August 24, 2005
(AS/SL)

PCT/EP2004/00044; PCT/EP03/09349; US 10/498,058; US 10/480,597; US 10/477,180; and US 10/485,960
Our ref.: Case 51856

Dear Mr. May,

As you know, our client is pursuing in the USA the patent granting process for the applications named in the subject line, for which the signing of the "Assignments" and the "Declaration for Patent Application and Power of Attorney," respectively, would be necessary.

The contested process concerning this matter in Germany is also known to you.

In order to give you the opportunity to be able to properly sign the "Assignment" formally, herewith we are handing over to you as an attachment to this letter on the following protective rights:
PCT/EP2004/00044
PCT/EP03/09349
US 10/498,058
US 10/480,597
US 10/477,180
US 10/485,960
an "Assignment" and also a combined "Declaration for Patent Application and Power of Attorney," and copies of the relevant documents of the corresponding file portions (submitted application text, file history, state of the art) for your review and for your information.

Herewith, we request that you sign the enclosed "Assignment" and also the combined "Declarations for Patent Application and Powers of Attorney" in a legally binding way and to return them to us at the latest by
September 7, 2005.

Sincerely,
Becker Kurig Straus
[signature]
Dr. Alexander Straus

Attachments
as mentioned above
cc: Copy of the letter (without attachments) to Peters Schönberger & Partners

[two copies of same ticket]
Waiting/Working time in min
Confirmed by [signature]

Delivery fee (net)
Waiting/Working time (net)

[Courier's] Ticket
Date: August 24, 2005
Car No.: 207
from Bavariastr. 7
to Inselkammerstr. 10

[stamp:] Becker Kurig Straus, Bavariastrasse 7, 80336 Munich

pp [illegible name]
Stamp/Signature of customer

Customer No. 664

[terms and conditions]

[signature]
Signature of recipient

A. Sawall

[Letterhead of Eurokurier]
Becker, Kurig, Strauss
Patent Attorneys
Bavariastr. 7
80336 Munich

[stamp:] Becker Kurig Straus, August 31, 2005

Dear Sir or Madam:

Herewith we confirm the orderly delivery of the courier messages from the above address to the receiver at Unterhaching 82008, Inselkammerstr. on August 24, 2005.

Sincerely,
[signature]
Th. Meyenberg
[Stamp:] Eurokurier

EXHIBIT 3

[Letterhead of Peters, Schönberger & Partners, Attorneys at Law]
[Stamp: Becker Kurig Straus, Bavariastrasse 7, 80336 Munich, August 30, 2005]

Urgent!!! Please expedite!

To: Dr. Alexander Straus
Fax No.: 089/716 303 11
From: Dr. Axel-Michael Wagner
No. of pages including cover sheet: 2
For further inquiries: Mrs. Barbara Götz, ext. 209
Re: ABAS vs May
Your ref.: 51856 case

August 30, 2005
93586/100832
AWA-dgu

Dear Dr. Straus,

In the matter named above, I asked Mr. May to respond to your letters of August 24, 2005. In the meantime, the set of attachments to these two letters has also been presented to me.

First of all, I note that our last correspondence of July 6, 2005, in the pending proceedings has led to a more extensive analysis on the petitioner's side with the individual inventions and the additional documents necessary for the desired signatures. Obviously, the petitioner's side is not actually of the opinion that it can force the issuing of blank declarations without the presentation of additional documents that would allow the inventor to evaluate the value of his statement precisely according to US law.

However, the extremely tight deadlines that have now been set by you are astonishing. These deadlines are even tighter than the deadlines set within the previous correspondence, although-as will be shown now-an enormous expense is necessary for reviewing the documents that have been handed over. The reason for this type of schedule is unclear since the matter will now be pending in court even longer. Just in terms of the sheer extent of the documents and due to his current workload, despite an illness, it appears to our client, who returned from his vacation at the end of last week and since then has been in very poor health, that he will be incapable of making a decision within the deadlines set by you regarding whether the statements again desired by you can be signed at all in this form with reference to the presented documents. This is independent of the question of whether our client is legally obligated in terms of the

already-raised objections (no consultation, limitations, right of retention, etc.) to give the statements also from a legal sense, if, theoretically, they could now be given.

[footer: list of partners' names and fields of practice]

The review of the presented documents-in part also in Chinese characters, in part also in Spanish-by our clients or the patent attorneys included by him, as well as the inclusion of an American (patent) lawyer, who can evaluate the demand on the issuing of the statements from the background of the extensive American enclosures and the matter contested in Germany, will take at least one month, possibly even longer, which is why a statement could be given at the earliest at the end of September/beginning of October 2005. After the review, we will revisit the matter without further inquiry.

Only in passing will I point out that apparently by far not all of the presented documents were transmitted in the sense of a complete file disclosure of the USPTO, but instead, at least in part, a prior selection of the documents had been performed. Therefore, there exists the additional problem that the documents must be checked here or by the American representatives of our clients for their completeness, which would not have been the case for a complete transmittal of copies of the official file.

Sincerely
[signature]
Dr. Axel-Michael Wagner
Attorney-at-law

EXHIBIT 4

Higgins, Brian

From: Higgins, Brian
Sent: Tuesday, August 23, 2005 1:49 PM
To: 'straus@galileolaw.de'; 'Klaus Gennen'; 'K. Nelte'; 'J.Kunzmann@cbh.de'
Cc: 'sharders@methode.com'; 'larry.rupert@methode.com'; Wolfe, Charles R. Jr.
Subject: Part 6 of 8

Attachments: 119508-00282.pdf

119508-00282.pdf
(4 MB)

Further to the e-mail below, please see the attached file: 119508-00282.

The assignment document (Lutz May to Abas, Inc.) is included in the attached file, but it does not constitute part of the initial application papers that were submitted to the U.S. Patent Office and could be removed prior to sending the application papers to Lutz May's attorney.

Best regards,

Brian Higgins

-----Original Message-----
From: Higgins, Brian
Sent: Monday, August 22, 2005 3:19 PM
To: 'straus@galileolaw.de'; Klaus Gennen; K. Nelte; 'J.Kunzmann@cbh.de'
Cc: 'sharders@methode.com'; 'larry.rupert@methode.com'; Wolfe, Charles R. Jr.
Subject: RE: Three issues regarding lawsuit agains Lutz May/Fast AG

Alexander,

The action item that we see regarding item 3) is to forward to Lutz May's attorney, via registered mail (or the equivalent, so we have documentation of the date mailed and date received), copies of specifications, drawings and claims accompanied by the corresponding inventor's declarations with a request that his client execute the declarations. We can expect that May will once again refuse to sign the declarations, but at least he will not be able to continue to argue that he was not presented with all of the application papers for his review prior to signing the declarations.

Thus, we will be sending to you later this week, via e-mail, copies of the relevant documents for each of the matters we are handling. You and the others have previously received some of the documents in various e-mails over the last 10 months (starting with the declarations and assignment documents back in November 2004); however, we have consolidated everything together in a single .PDF file to make things easier to handle on your end.

Best regards,

Brian Wm. Higgins, Esq.*

Blank Rome LLP
Watergate
600 New Hampshire Ave., N.W.
Washington, D.C. 20037

Phone: (202) 772-5814
Direct Fax: (202) 572-1458
Practice Group Fax: (202) 572-8398

Web: < http://www.blankrome.com/>

* Admitted to practice in the U.S. Patent & Trademark Office and Maryland only. Practice limited to matters and proceedings before federal courts and agencies.

EXHIBIT 5

Attorney Docket: 119508-00282

DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:
My residence, mailing address and citizenship are as stated below next to my name,
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: TORQUE SIGNAL TRANSMISSION
the specification of which

☐ is attached hereto

☒ was filed on September 24, 2003 as United States Application Number or PCT International Application Number PCT/EP03/10634 and (if applicable) was amended on _____

I hereby authorize our attorneys to insert the serial number assigned to this application.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 USC §119			
APPLICATION NO.	COUNTRY	DAY/MONTH/YEAR FILED	PRIORITY CLAIMED

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

PROVISIONAL APPLICATION(S) UNDER 35 U.S.C. §119(e)	
APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under 35 U.S.C. §120 of any United States application, or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. §112.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

PRIOR U.S./PCT INTERNATIONAL APPLICATION(S) DESIGNATED FOR BENEFIT UNDER 35 U.S.C. §120		
APPLICATION NO.	FILING DATE	STATUS — PATENTED, PENDING, ABANDONED

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith: Victor M. Wigman, Reg. No. 25,201; George C. Myers, Jr., Reg. No. 27,040; Donald R. Greene, Reg. No. 22,470; Michael C. Greenbaum, Reg. No. 28,419; Charles R. Wolfe, Jr., Reg. No. 28,680; Michael D. White, Reg. No. 32,795; Brian C. Jones, Reg. No. 37,857; David J. Edmondson, Reg. No. 35,126; Denise C. Lane, Reg. No. 42,780; Peter Weissman, Reg. No. 40,220; Brian WM. Higgins, Reg. No. 48,443; Minh-Quan K. Pham, Reg. No. 50,594; Thomas L. Willis, Jr., Reg. No. 53,778; and Tara L. Hoffman, Reg. No. 46,510.

Correspondence Address:

Blank Rome LLP
600 New Hampshire Avenue, N.W.
Washington, DC 20037
TEL (202) 772-5800 FAX (202) 572-8398
Customer No: 27557

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of sole or first inventor (given name, family name): Lutz Axel MAY	
Signature:	**Date:**
Residence: Wolfratshauser Strasse 23a, 82538 Gelting, GERMANY	**Citizenship:** German
Mailing Address: Same as residence.	

Full Name of additional joint inventor (given name, family name):	
Signature:	**Date**
Residence:	**Citizenship:**
Mailing Address: Same as residence.	

Full Name of additional joint inventor (given name, family name):	
Signature:	**Date:**
Residence:	**Citizenship:**
Mailing Address: Same as residence.	

Full Name of additional joint inventor (given name, family name):	
Signature:	**Date:**
Residence:	**Citizenship:**
Mailing Address: Same as residence.	

Full Name of additional joint inventor (given name, family name):	
Signature:	**Date:**
Residence:	**Citizenship:**
Mailing Address: Same as residence.	

☐ ***Additional joint inventors are named on separately numbered sheets attached hereto.***

ASSIGNMENT

THIS ASSIGNMENT, made on the date set forth below by Lutz Axel May, a German citizen, residing at Wolfratshauser Strasse 23a, Geretsried, 82538, Germany, hereinafter referred to as ASSIGNOR, witnesseth:

WHEREAS, said ASSIGNOR has invented certain new and useful improvements in TORQUE SIGNAL TRANSMISSION set forth in an International Application filed on September 24, 2003, in the office of the International examining authority and accorded Application No. PCT/EP03/10634, and set forth in a corresponding British application,

WHEREAS Abas, Inc., a Delaware corporation having a principal place of business at 7401 W. Wilson Avenue, Chicago, Illinois 60706, is desirous of acquiring the entire right, title and interest in and to said invention as set forth in said patent applications in the United States and around the world;

NOW, THEREFORE, for good and valuable consideration, receipt of which is hereby acknowledged, ASSIGNOR, by these presents does sell, assign, and transfer unto said ASSIGNEE, the entire right, title, and interest in and to the above-mentioned invention, said patent application for Letters Patent, and any and all Letters Patent or Patents in the United States of America and all foreign countries which may be granted therefor and thereon, and in and to any and all divisions, continuations, and continuations-in-part of said application, or reissues or extensions of said Letters Patent or Patents, and all rights under the International Convention for the Protection of Industrial Property, the same to be held and enjoyed by the said ASSIGNEE, for its own use and behoof and the use and behoof of its successors, legal representatives and assigns, to the full end of the term or terms for which Letters Patent or Patents may be granted, as fully and entirely as the same would have been held and enjoyed by the ASSIGNOR, had this assignment not been made.

ALSO, ASSIGNOR hereby agrees to execute any documents that legally may be required in connection with the filing, prosecution and maintenance of said application or any other patent application(s) or inventor certificate(s) in the United States and in foreign countries for said Letters Patent, including additional documents that may be reasonably required to affirm the rights of ASSIGNEE in and to said invention and Letters Patent, all without further consideration.

ASSIGNOR also agrees, without further consideration and at ASSIGNEE'S expense, to identify and communicate to ASSIGNEE at ASSIGNEE'S reasonable request documents and information concerning the invention that are within ASSIGNOR'S possession or control, and to provide further assurances and testimony on behalf of ASSIGNEE that lawfully may be required of ASSIGNOR in respect of the prosecution, maintenance and defense of any patent application or patent encompassed within the terms of this instrument. ASSIGNOR'S obligations under this instrument shall extend to ASSIGNOR'S heirs, executors, administrators and other legal representatives.

ALSO, ASSIGNOR hereby authorizes and requests that the examination authority in any and all states to issue any and all Letters Patents or Patents referred to above to ASSIGNEE, as the ASSIGNEE of the entire right, title and interest in and to the same, for ASSIGNEE'S sole use and behoof; and for the use and behoof of ASSIGNEE'S legal representatives and successors, to the full end of the term for which such Letters Patent or Patents may be granted, as fully and entirely as the same would have been held by ASSIGNOR had this assignment not been made.

ALSO, ASSIGNOR authorizes any member of the firm of Blank Rome LLP to insert or complete any information in this document needed to effect its recordal in the U.S. Patent & Trademark Office.

Effective this ____ day of _____ [month], in the year _____.

Lutz A. May

_____
[Signature]

The foregoing instrument was subscribed and sworn before me this _____ day of _____, 2004, by Lutz A. May.

_____
Notary Public

My Commission Expires: _____

THE OFFICIAL DATE STAMPED HEREON BY THE U.S. PATENT AND TRADEMARK OFFICE WILL ACKNOWLEDGE RECEIPT OF THE FOLLOWING:

Applicant: Lutz Axel MAY
Serial No.: To Be Assigned
Filing Date: March 25, 2005
For: **TORQUE SIGNAL TRANSMISSION**

ENCLOSURES:

- Transmittal Letter to the United States Designated/Elected Office (in duplicate)
- Preliminary Amendment
- Specification, claims and abstract (21 pages)
- Drawings (7 Sheets)
- Unexecuted Declaration (2 pages)
- Copy of WO/2004/029569 A1
- International Search Report (English)
- IDS with FORM PTO-1449 and references
- Recordation Transmittal an Assignment
- Check No. _____ in the amount of $1,240

CRW/BWH:dlc
March 25, 2005

Attorney Docket No. 119508-00282

BLANK ROME LLP

THE OFFICIAL DATE STAMPED HEREON BY THE U.S. PATENT AND TRADEMARK OFFICE WILL ACKNOWLEDGE RECEIPT OF THE FOLLOWING:

Applicant: Lutz Axel MAY
Serial No.: To Be Assigned
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THE OFFICIAL DATE STAMPED HEREON BY THE U.S. PATENT AND TRADEMARK OFFICE WILL ACKNOWLEDGE RECEIPT OF THE FOLLOWING:

Applicant: Lutz Axel MAY
Serial No.: To Be Assigned
Filing Date: March 25, 2005
For: **TORQUE SIGNAL TRANSMISSION**

10/529326

ENCLOSURES:

- Transmittal Letter to the United States Designated/Elected Office (in duplicate)
- Preliminary Amendment
- Specification, claims and abstract (21 pages)
- Drawings (7 Sheets)
- Unexecuted Declaration (2 pages)
- Copy of WO/2004/029569 A1
- International Search Report (English)
- IDS with FORM PTO-1449 and references
- Recordation Transmittal an Assignment
- Check No. 13017 in the amount of $1,240

EARLY SERIAL NO. REQUESTED

CRW/BWH:dlc
March 25, 2005

Attorney Docket No. 119508-00282

BLANK ROME LLP

JC03 Rec'd PCT/PTO 25 MAR 2005

BLANK ROME LLP

CHECK NO. 13012

VENDOR #	INVOICE #	DATE	INVOICE AMOUNT	INVOICE DESCRIPTION	AMOUNT PAID
00896	119508-00282	03-24-05	1,240.00	BASIC FILING FEE $300; UTILITY SEARCH FEE $500; UTILITY EXAM FEE $200; ASSIGNMENT RECORDATION FEE $40; EXTRA INDEPENDENT CLAIM FEE $200- TOTAL $1240.00 FOR A NEW SERIAL NUMBER	1,240.00

THE FACE OF THIS DOCUMENT HAS A COLORED BACKGROUND THAT IS SENSITIVE TO CHEMICAL ALTERATION AND FLUORESCENT FIBERS WHEN EXPOSED TO ULTRAVIOLET LIGHT.

BLANK ROME LLP
COUNSELORS AT LAW
600 NEW HAMPSHIRE AVENUE, NW
WASHINGTON, DC 20037
(202) 944-3000

CHECK NO. 13012

WASHINGTON DISBURSEMENT ACCT
55-136/312
03/24/05

$1,240.00

ONE THOUSAND TWO HUNDRED FORTY AND 00/100 DOLLARS

PAY TO THE ORDER OF **U.S. COMMISSIONER OF PATENTS AND TRADEMARKS**

VENDOR REF:

COMMERCE BANK
DELAWARE

⑈013012⑈ ⑆031401017⑆ 95 00000 42⑈

THIS DOCUMENT CONTAINS MICROPRINTING IN BORDER AND A REFLECTIVE WATERMARK ON BACK. HOLD AT AN ANGLE IN NATURAL OR ULTRAVIOLET LIGHT TO VIEW THE IMAGE.

PTO-1390 (Rev. 02-2005)
Approved for use through 3/31/2007. OMB 0651-0021
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	
119508-00282	
U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	
Not yet assigned	

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP03/10634	September 24, 2003	September 25, 2002

TITLE OF INVENTION: TORQUE SIGNAL TRANSMISSION

APPLICANT(S) FOR DO/EO/US: Lutz Axel MAY

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☐ The US has been elected (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ Is attached hereto.
   b. ☐ Has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A preliminary amendment.
14. ☐ An Application Data Sheet under 37 CFR 1.76.
15. ☐ A substitute specification.
16. ☐ A power of attorney and/or change of address letter.
17. ☐ A computer readable form of the sequence listing in accordance with PCT Rule 13*ter*.2 and 37 CFR 1.821 – 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4)
20. ☒ Other items or information: Form PTO-1449 and references

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NO.
Not yet received	PCT/EP2003/010634	119508-00282

The following fees have been submitted	CALCULATIONS	PTO USE ONLY
21. ☒ Basic national fee $300	$300	
22. ☐ Examination fee If International preliminary examination report prepared by USPTO and all claims satisfy provisions of PCT Article 33(1)-(4) ..... $100 All other situations $200	$200	
23. ☐ Search fee Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority ..... $100 International Search Report prepared and provided to the Office ..... $400 All other situations $500	$500	
TOTAL OF 21, 22 and 23 =	$1,000	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is $250 for each additional 50 sheets of paper or fraction thereof.		

Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
- 100 =	/50 =		x $250	$	
Surcharge of $130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h))				$	

CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE		
Total Claims	16	- 20 =		x $ 50	$	
Independent Claims	4	- 3 =	1	x $200	$200	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ $360	$	
				TOTAL OF ABOVE CALCULATIONS =	$1,200	
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.					$	
				SUBTOTAL =	$1,200	
Processing fee of $130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)). +					$	
				TOTAL NATIONAL FEE =	$1,200	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28,3.31). $40.00 per property +					$ 40	
				TOTAL FEES ENCLOSED =	$1,240	
				Amount to be refunded:		
				Amount to be charged:		

a. ☒ A check in the amount of $ 1,240.00 to cover the above fees is enclosed.

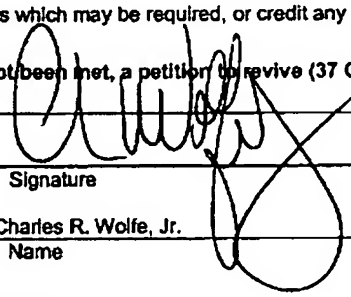
b. ☐ Please charge my Deposit Account No. 23-2185 in the amount of $ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 23-2185. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the international application to pending status.

SEND ALL CORRESPONDENCE TO:

CUSTOMER NO.: 27557
BLANK ROME LLP
600 New Hampshire Avenue, N.W.
Washington, D.C. 20037
Tel: (202) 772-5800
Fax: (202) 572-8398



Signature

Charles R. Wolfe, Jr.
Name

28,680
Registration No.

March 25, 2005
Date

FORM PTO-1390 (REV. 02-2005)

PTO/SB/07 (08-03)
Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET

Substitute for Form PTO-1360
(For use with Form PTO/SB/06)

Application Number	Filing Date
	3-24-05

Applicant(s) Fritz Hel May

* May be used for additional claims or amendments

CLAIMS AS FILED			AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT		*			*			*		
	Indep	Depend	Indep	Depend	Indep	Depend		Indep	Depend		Indep	Depend		Indep	Depend
1	1						51								
2		1					52								
3		1					53								
4		1					54								
5		1					55								
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7	1						57								
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50							100								
Total Indep	4						Total Indep								
Total Depend	12						Total Depend								
Total Claims	16						Total Claims								

119508-2822

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of	)	
	)	
Lutz Axel MAY	)	Group Art Unit: TBD
	)	
Serial No. TBD	)	Confirmation No. TBD
	)	
Filed: March 25, 2005	)	Examiner: TBD
	)	
For: TORQUE SIGNAL TRANSMISSION	)	Atty. Dkt. No.: 119508-00282

PRELIMINARY AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Kindly enter this Preliminary Amendment in the record prior to examination of the claims on the merits. This paper includes the following sections:

(1) **Amendments to the claims,** which are shown in the listing of claims that begins on page 3 of this paper;

(2) **Amendments to the specification,** which begins on page 7 of this paper; and

(3) **Remarks,** which begin on page 8 of this paper.

If a Petition for extension of time is require to render this submission timely and either is not filed concurrently herewith or does not suffice to render this submission timely, the Applicant hereby petitions under 37 C.F.R. §1.136(a) for such an extension for as many months as are required to render this submission timely. Any fees due in connection with said Petition are authorized. Please charge any deficiency in fees, or credit any overpayment thereof, to BLANK ROME LLP, Deposit Account No. 23-2185 (Ref. No. 119508-00282).

Respectfully submitted,

Charles R. Wolfe, Jr.
Registration No. 28,680

BLANK ROME LLP
Watergate
600 New Hampshire Ave., N.W.
Washington, DC 20037
Telephone: 202-772-5800

Date: 3/25/05

AMENDMENTS TO CLAIMS

Listing of Claims:

Claim 1 (Currently amended): A torque transducer comprising:

a shaft subject to torque about a longitudinal axis;

a transducer element integral with or carried by the shaft and remanently ~~magnetised~~ magnetized to emanate a component of magnetic field that is dependent on torque applied about said axis,

a sensor coil disposed about said element to generate a voltage/current in response to changes in said component,

a load connected to said sensor coil to enable a current to circulate in 10 the sensor coil; and

a receiver unit remote from said coil and responsive to a field emanated by said sensor coil to generate a torque-dependent signal

Claim 2 (Original): A torque transducer as claimed in Claim 1 in which said receiver unit comprises a coil~~, preferably wound on a magnetic core~~.

Claim 3 (Original): A torque transducer as claimed in Claim 1 in which the receiver unit coil is wound on a ferrite core.

Claim 4 (Currently amended): A torque transducer as claimed in ~~Claim 1, 2 or 3~~ Claim 1 in which said load comprises a capacitor connected across said sensor coil to enhance a field component emanated thereby.

Claim 5 (Currently amended): A torque transducer as claimed in ~~any preceding claim~~ Claim 1 in which said transducer element comprises a region integral with said shaft and remanently ~~magnetised~~ magnetized with an annulus of longitudinal ~~magnetisation~~ magnetization (axially-directed ~~magnetisation~~ magnetization) which exhibits profile shift, and said sensor coil comprises two spaced coil sections which are aligned with respective response maxima and are connected such that the voltages induced therein are summed.

Claim 6 (Currently Amended): A torque transducer system comprises a torque transducer which is as claimed in ~~any one of Claims 1 to 5, and~~ Claim 1 wherein said shaft is coupled to or is a part of a source of a torque pulse, such as a power torque tool.

Claim 7 (Original): A torque transducer assembly comprising:

a housing having an opening therethrough;

a torque transmission shaft extending in said opening and rotatable about an axis extending through said opening, said shaft having respective end portions accessible from exteriorly of said housing,

a torque transducer element integral with, or carried by, said shaft to emanate a magnetic field dependent on the torque in the shaft,

a coil coaxial with said element and adjacent thereto; and for sensing the torque-dependent field,

a load, preferably a capacitative load, connected across the coil to enable current to circulate therethrough for emanating a field externally of the assembly that is dependent on changes in torque in the shaft.

Claim 8 (Original): A torque transducer assembly as claimed in Claim 7 in which one end portion of said shaft projects exteriorly of said housing and provides an output portion of the shaft.

Claim 9 (Currently Amended): A torque transducer assembly as claimed in Claim 7 ~~or 8~~ in which said housing is configured to enable it to be secured against rotation.

Claim 10 (Original): A torque transducer assembly as claimed in Claim 9 further comprising a member having a first portion engaged with the housing and second portion engageable with the body of a power torque tool to secure the housing against rotation with respect to said body.

Claim 11 (Currently Amended): A torque transducer comprising:

a shaft subject to torque about a longitudinal axis;

a transducer element integral with or carried by the shaft and remanently ~~magnetised~~ magnetized to emanate a component of magnetic field that is dependent on torque applied about said axis,

a sensor coil disposed about said element to generate a voltage/current in response to changes in said component,

a power supply unit comprising a rectifier arrangement connected to said sensor coil to derive a unipolar electrical supply from changes of torque sensed by said sensor coil; and

signalling means responsive to voltage/current signals in said sensor coil to transmit the signals in a wire-less manner for remote detection, said signalling means being powered by said electrical supply.

Claim 12 (Currently Amended): A torque transducer as claimed in Claim 11 in which said transducer element comprises a. region integral with said shaft and remanently ~~magnetised~~ magnetized with an annulus of longitudinal ~~magnetisation~~ magnetization (axially-directed ~~magnetisation~~ magnetization) which exhibits profile shift, and said sensor coil comprises two spaced coil sections which are aligned with respective response maxima and are connected such that the voltages induced therein are summed.

Claim 13 (Currently Amended): A torque transducer comprising:

a shaft subject to torque about a longitudinal axis;

a transducer element integral with or carried by the shaft and remanently ~~magnetised~~ magnetized to emanate a component of magnetic field that is dependent on torque applied about said axis,

a sensor coil disposed about said element to generate a voltage/current in response to changes in said component,

a power supply unit comprising a rectifier arrangement connected to said sensor coil to derive a unipolar electrical supply from changes of torque sensed by said sensor coil;

a sensor arrangement responsive to said torque-dependent magnetic field component to provide a torque-dependent signal; and

~~signalling~~ signaling means responsive to a torque-dependent signal to transmit the signal in a wire-less manner for remote detection, said ~~signalling~~ signaling means and, if appropriate, said sensor arrangement being powered by said electrical supply.

Claim 14 (Currently amended): A torque transducer system comprises a torque transducer which is as claimed in ~~Claim 11, 12 or 13, and~~ Claim 11 wherein said shaft is coupled to or is a part of a source of a torque pulse, such as a power torque tool.

Claim 15 (New): A torque transducer system comprises a torque transducer which is as claimed in Claim 13 wherein said shaft is coupled to or is a part of a source of a torque pulse, such as a power torque tool.

Claim 16 (New): A torque transducer as claimed in Claim 1 in which said receiver unit comprises a coil and wherein said coil is wound on a magnetic core.

AMENDMENTS TO THE SPECIFICATION

Please insert the following Abstract at the end of the specification and claims:

ABSTRACT

The present invention relates to a torque transducer with a shaft subject to torque about a longitudinal axis. It also relates to a transducer element integral with or carried by the shaft and remanently magnetised to emanate a component of mangetic field that is dependent on torque applied about said axis. A sensor coil is disposed about said element to generate a voltage/current in response to changes in said component. A load is connected to said sensor coil to enable a current circulate in the sensor and a receiver unit remote from said coil and responsive to a field emanated by said sensor coil to generate a torque-dependent signal.

REMARKS

This Preliminary Amendment is being filed in conjunction with a national stage patent application stemming from an international application. The claims submitted herewith have been amended to remove the multiple dependencies that were present in the claims of the international application, as well as to conform to PTO patent practice rules as necessary, and to amend certain claim terms such as "magnetisation" (i.e., with an "s") to read "magnetization" (i.e., with a "z"). No new matter has been introduced.

APPLICATION FOR UNITED STATES LETTERS PATENT

TITLE: TORQUE SIGNAL TRANSMISSION

INVENTOR: Lutz Axel MAY

ASSIGNEE: Abas, Incorporated

BLANK ROME LLP
The Watergate
600 New Hampshire Avenue, NW
Washington, DC 20037
(202) 772-5800
(202) 572-8398 (facsimile)

Docket No. 119508-00282

Title: Torque Signal Transmission

FIELD OF THE INVENTION

This invention is concerned with a method of and apparatus for the sensing of torque and the transmission of a torque-dependent signal to a remote measurement apparatus by a wireless technique. In this content, wireless transmission means signal transmission without the need of a cable or other like physical connection.

The invention finds particular utility in a torque-generating system in which the torque is generated as pulses of torque. An example of such pulse torque generation is in power fastening tools for fastening or tightening nuts onto bolts or studs for example. Power fastening tools find application in many industries, a major one of which is automobile assembly.

BACKGROUND TO THE INVENTION

The measurement of torque applied to a fastening, such as a nut and bolt, has long presented problems in determining the point at which a desired torque value is achieved when using pulse-type power torque tools. Among the techniques developed for measuring pulsed torque are those based on magnetic transducer technology in which a magnetised transducer is incorporated in or coupled to a torque transmission shaft in a power tool and a torque-dependent magnetic field component is sensed by a non-contact sensor arrangement to develop a torque-representing signal which is transmitted by an electrical connection to signal-processing circuit. The complete torque measuring assembly can be mounted in the tool. An alternative is to transmit a torque-dependent signal from the tool to a remote signal processing circuit as by a cable or wire connection. Even if the signal

were to be transmitted by a wireless connection, e.g. an infra-red link, it is necessary to provide power to the tool end of the link.

There would be considerable benefit in a torque sensor with remote signalling to a processor which did not require electrical power to be provided in association with the sensor. A torque sensor of this kind would be of particular value applied in a power torque tool adaptor of the kind described in British patent application GB 0219745.7 filed 23rd August 2002 which is incorporated herein by reference and to which further reference will be made below.

The application of magnetic transducer technology for torque measurement in a power impact tool is disclosed in U.S. patent 6 311 786 and in its published continuation application US 2002/0020538 in which torque measurement and control is contained within the tool. The torque transducer uses a ferromagnetic sensor and specifically discloses a magneto-elastic ring coupled to the output shaft of the tool. An impact tool control method and apparatus is described in International patent application publication WO01/44776. The control system uses a magneto-elastic torque transducer mounted exteriorly of the tool in which the magneto-elastic transducer element is an integral portion of a shaft through which torque is transmitted. This document also discloses the implementation of the control system as a retrofit system for use in controlling an existing impact tool. The magnetic field generated by the transducer element is detected by a detector which can be a coil of wire circumferentially arranged around the transducer or other device. The coil is connected into the input of an integrator in a signal processing circuit.

The PCT patent application PCT/EP02/06960 filed 24th June 2002, the disclosure of which is incorporated herein by reference, discloses the control of a pulsed torque tool using a magnetic-based torque transducer which has a

transducer element or region integral with the output shaft of the tool. The control apparatus including the transducer is disposed interiorly of the power torque tool.

Above-mentioned application GB 0219745.7 describes an adaptor attachable to a conventional power torque tool of the pulsed-type whereby torque measurement and control can be exercised on the tool. In GB 0219745.7 the adaptor is connected to a unit containing external circuitry by a cable. It may be coupled by a wire-less link, e.g. an IR link, to transmit a torque-dependent signal to the external unit but in that case, the adaptor requires electrical power for its operation.

SUMMARY OF THE INVENTION

One aspect of the present invention is based on the concept of transmitting a torque-dependent signal to a remote unit by means of an emanated field. In particular it is applied to modify an adaptor of the kind described in GB 0219745.7 so that the adaptor is active in the sense of being magnetically active to generate the torque-dependent signal but is passive in the sense of not requiring a source of electrical power.

Another aspect of the invention is based on the concept of deriving an electrical power supply from torque pulses to power a signalling system for transmission to a remote unit and, if appropriate, to power a sensor arrangement.

Aspects and features of the present invention are set forth in the claims following this description.

The invention and its practice will be further described with reference to an embodiment illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates an adaptor for fitting to a power torque tool to transmit a torque-dependent signal in accord with the present invention;

Fig. 2 illustrates the internal construction of an adaptor based on that disclosed in GB 0219745.7

Fig. 3 shows a shaft with an integral magnetised transducer region and a sensor coil;

Fig. 4 is a response curve as a function of the axial position of the sensor coil for a transducer region having profile-shift longitudinal magnetisation;

Fig. 5 shows the connection of the arrangement of Fig. 3 with a power supply and signal transmission circuit, all energised by sensed torque pulses;

Fig. 6 shows a modification of the arrangement of Fig. 3 to use a capacitative load;

Fig. 6a shows the circuit used to investigate the "resonance" effect of a capacitative load;

Figs. 7a to 7c are response curves to pulse torques of lower, medium and higher torque respectively using the circuit of Fig. 6a;

Fig. 8 shows a simplified illustration of a torque adapator to which a coil sensor is applied;

Fig. 9 is a preferred coil arrangement for use with the response curve of Fig. 4 and

Fig. 9a is the preferred connection of the two coil sections of the coil arrangement of Fig. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a conventional power torque tool 10, such as an impact-type fastening tool which provides torque pulses at an output shaft 12. The tool may also be of the type in which pulses are generated by controlled actuation of a piston and cylinder mechanism. The tool illustrated is powered by compressed air through line 14. It is conventional to fit a load-engaging adaptor on the end 12a of the shaft 12 distal the power tool for transmitting torque to the load, e.g. a nut or bolt head. Such an adaptor is exemplified in PCT/EP02/06960. The adaptor is a passive mechanical article for transmitting torque from the shaft to the load. As above-mentioned in the system described in PCT/EP02/06960, torque measurement and control is performed within the tool body 10.

In the illustrated embodiment of the present invention a torque sensor adaptor 20 is provided to enable torque measurement and control to be exercised on a conventional pulsed torque tool not containing such provision. The adaptor 20 couples to the tool output shaft at one end and receives a conventional passive adaptor for engaging a load at the other end. The adaptor incorporates a torque transducer arrangement using a magnetic-based torque transducer element. The adaptor 20 can be characterised as an active device in contrast to prior passive devices. However, as will become clear hereinafter, the adaptor is magnetically active as regards torque sensing but is passive in the sense of requiring no electrical power supply for operation. The adaptor 20 emanates a field carrying a torque-dependent signal as indicated by arrow 50 which is received by a remote receiver unit 52. Unit 52 is connected by cable connection 22 to a signal processing and controller unit 30 which in turn supplies a shut-off signal over cable connection 32 to an air-valve unit 40 acting in line 14. The unit 30 may include a display 34, e.g. an LCD display, for displaying relevant parameters on a manually actuable key pad 36 for entering control instructions and data to a programmed

microprocessor (not shown) housed in unit 30. The unit 30 can be mounted or carried so as to be free of the vibration generated in operation of the tool 10. The receiver unit 52 may be included within unit 30. As schematically illustrated by chain lines 24 the adaptor 20 has a body portion 26 which is securable or attachable to the body of the power tool 10 as will be described below. The adaptor has a torque transmitting shaft extending through the body and having an output end 28.

Fig. 2 shows one form of construction for the adaptor 20 which is constructed to transmit torque about an axis A-A. It is a general aim of the construction to keep the axial length of the torque transmitting shaft as short as possible. The adaptor has a housing 26 with an internal circular bore 27 in which is mounted a torque transmitting transducer assembly 60 rotatable within the housing 26 about central axis A-A.

The assembly 60 has a shaft portion 62 disposed between an input portion 64 and an output portion 66 providing the output end 28 of Fig. 1. The input and output roles are reversible but the shaft portions 62 and 64 are shaped in accord with usual power tool practice. The input portion 64 is configured for engagement with the shaft 12 of tool 10. It is of larger diameter than the shaft portion 62 and includes an axial blind bore 68 configured to fit on the distal end 12a of the tool output shaft 12. For example, if the tool output shaft is of a square cross-section, the bore 68 is of a matching square section. The output portion 66 is shown in this embodiment as a square cross-section shaft similar to the output shaft 12 of the power tool and to which a passive load-engaging adaptor can be fitted. It will be understood that the input and output portions of the assembly 60 can be configured as required by the tool and the load adaptor respectively; or the output portion 66 could be configured for direct engagement with the load.

The shaft portion 62 is of circular cross-section and is radially-spaced from the adjacent inner surface of housing 26. Shaft portion 62 is magnetised at 70 to provide a torque-sensitive transducer element or region which emanates a torque-dependent magnetic field which is sensed by a sensor arrangement to be described and not shown in Fig. 2.

The region 70 is a region of stored magnetisation. That is, it is remanently magnetised to store a permanent magnetisation. Preferably the magnetisation is an annulus of longitudinal magnetisation about axis A-A. the longitudinal magnetisation is in the direction of axis A-A, e.g. as illustrated N-S. The longitudinal magnetisation may be of the kind known as circumferential sensing as disclosed in WO01/13081 or, preferably, of the kind known as profile-shift (axial or radial sensing) as disclosed in WO01/79801. Another torque measuring technique which does not require a region of stored magnetisation is that disclosed in British patent application GB 0204213.3 filed 22nd February, 2002. In this technique the transducer element is not a previously magnetised or (encoded) region of the shaft but is a defined region in which the torque-sensitive element is established in use.

Looking at further details of the constructions of the adaptor of Fig. 2, the output portion of square cross section includes recess 65 for co-operating with a standard passive mechanical adaptor. The transducer region 62 is located for rotation within the housing by a plain bearing provided by an annular bush 80 of a plastics material which is bonded to or otherwise secured against rotation to a forward (i.e. toward the output end) inside surface 27a of the housing 26. The interior diameter of bush 80 is slightly greater than the diameter of region 62, other than for a forward lip 82 which bears against the shaft.

The rearward end of bush 80 seats against an internal step 27b of housing 26 and also provides an abutment 84 for axially locating the transducer assembly

and specifically a forward surface of the enlarged input portion 64. The input portion is sized to rotate freely within a part 26a of the housing of reduced internal diameter extending from step 27b to a rearward internal step 27c. Step 27c lies adjacent a circumferential groove 67 in the input portion 64. An annular bushing 86 of a low friction, self-lubricating material is received in the groove and engages the interior surface of housing 26 and is axially located by step 27c. The bushing 86, and therewith the transducer assembly 60 is retained in the housing by an internally-located press-fit retaining ring 88 at the rear of the housing. The housing 26 not only provides mechanical support and protection but provides a magnetic shield for the transducer assembly. It will be understood that the construction illustrated in Fig. 2 is diagrammatic in nature.

One feature of the assembly 60 of Fig. 2 is that the input portion 64 terminates at 64a flush with the rearward end 26b of the housing 26 or within the axial confines of the housing which is in accord with the desire to keep the overall length of the active adaptor as small as possible. The square-section bore 68 for engaging the output shaft of the power tool is contained within the housing. The assembly 60 is a push fit into the housing 26 from its rearward end.

To perform the function generally indicated at 24 in Fig. 1 of preventing rotation of the adaptor housing and to retain the output shaft 12a of the power tool engaged within the bore 68, the exterior of housing 26 is adapted to retain one end of a stiff helical spring (or more than one such spring) the other end of which is retained on the housing of the power tool. The spring, thus retained, is in an axially stretched state (in tension) so that the tension maintains the active adaptor engaged with the power tool. It has also been found that the flexibility of the retaining spring enables the power tool fitted with the active adaptor to accommodate the variations in the angle between the torque axis and the load being fastened that occur in practical use of the

tool. It will be understood the plain bearing type of rotary support provided by bush 80 and bushing 86 could be substituted by other means of bearing support.

The description given so far with reference to Figs. 1 and 2 closely follows the description of the adaptor disclosed in GB 0219745.7. Attention will now be given to the modifications to that design by which the present invention is implemented.

Referring to Fig. 1, in GB 0219745.7 the adaptor 20 is connected directly to the processing unit by cable 22. The adaptor houses a magnetic field sensor arrangement co-acting with a transducer region which is connected via cable 22 into a signal conditioning circuit in unit 30; or which is connected to a signal conditioning circuit within the adaptor which circuit then transmits a torque-representing signal to the unit 30 over cable 22. Either way, the operation of the sensor devices in adaptor 20 requires electrical power to be supplied in or to the adaptor. The substitution of a wire-less link, e.g. an infra-red (IR) link, for the cable 22 would still require the supply of power in or to the adaptor. The foregoing disadvantage can be obviated by the torque sensing and signal sending techniques now to be described. The technique is of general utility and is not restricted to being applied to the adaptor under specific consideration.

Fig. 3 shows a ferromagnetic shaft 100 rotatable about a longitudinal axis A-A. An integral portion 70 of the shaft is encoded with a remanent, annular magnetisation of the kind referred to a profile-shift as described in above-mentioned WO01/96826. A single coil is wound closely about the shaft. For the purposes of the immediate discussion the coil is movable axially with respect to the region 70. The coil is terminated in a low value resistor R, of say 270Ω. Fig. 4 shows a graph of the voltage across the resistor (current induced to circulate in the coil) as a function of the axial position of the coil

relative to region 70 when the transducer region is subject to a torque pulse of a given value. Current is induced in the coil by the resultant torque-dependent change in the magnetic flux distribution acting on the coil. M The coil current is proportional to the rate of change of flux during the torque impulse. By way of example, the encoded region 70 may be 22 mm wide and the width of the coil 4-5 mm with the coil having 300 turns or more.

When a torque pulse is applied to one end shaft 100, it propagates along the shaft "winding up" the shaft. There is then a lesser recoil pulse of opposite polarity dependent on the elasticity of the shaft material. This phenomenon will appear in torque pulse graphs described later.

Reverting to Fig. 4 it will be seen that the voltage across resistor R is at a maximum at two points 72a, 72b spaced from the centre-line 74 of the region 70. The polarity reverses as the coil passes through alignment with the centre line and investigation thus far has revealed that the maximum voltages are achieved when the coil is aligned with the sweet spots described in WO01/96826 with reference to Fig. 30 thereof.

The voltage/current induced in the coil 110 has two possible functions. The first is as a source of electrical energy. That is the transducer provides a mechanical(torque)-to-electrical energy converter. The second is as a torque-dependent signal usable in a subsequent torque measurement and control process. Fig. 5 is a diagrammatic illustration of the use of the voltage/current induced in the coil for both possibilities.

In Fig. 5 the coil 110 is connected to a power control unit 112 which generates a supply voltage V_s at terminal 114. The unit 112 may include a rectifier arrangement, connected across the coil to develop a usable power supply voltage from the voltage at the coil terminals. The rectifier arrangement is preferably of the full wave bridge type to use excursions of both polarities of the coil output voltage. The rectifier arrangement feeds a smoothing

capacitor to derive a smoothed unipolar voltage from the rectifier arrangement and a low power voltage regulator device may also be employed. The supply voltage V_s is used to power the torque signal transmission part of the arrangement of Fig. 5.

The torque-dependent signal voltage developed across the coil is applied as the input to a signal conditioning circuit 120 which processes the signal to generate a torque signal V_T which modulates a transmitter unit 122 to transmit the torque-representing signal by any form of wireless connection 50, such as light (visible or otherwise), radio, sound, induction etc.

The coil 110 may be tightly wrapped around the region 70 of shaft 100 at an axial position at which maximum energy output is generated, e.g. a sweet spot as discussed with reference to Fig. 4. Consequently if the coil is to rotate with the shaft and if the shaft is to continue to rotate under successive torque pulses, it may be necessary to connect the coil to the remainder of the circuitry through slip rings. Alternatively the coil 110 may be wound sufficiently spaced from the shaft to allow the shaft to rotate within a fixed coil. The shaft may be a steel of the type mentioned below.

A presently preferred embodiment of the invention will now be described which makes use of remote signalling but does not require the provision of a power supply to energise a transmitter device. This implements the second function mentioned above.

It will be noted that the power generating function of the coil 110 could be used for powering a magnetic field sensor arrangement using sensor devbices such as saturating core inductors, Hall effect devices or magnetoresistive devices. The torque-dependent signal thereby obtained modulates transmitter unit 122 for remote signalling as already described.

Fig. 6 is similar to Fig. 3 but shows a capacitor C connected across the coil 110. The coil may be in the range of 300 to 600 turns on a 15-18 mm diameter shaft of FV 250B steel. Other suitable steels are those known under the designations S155, SI56 and 14 NiCo14. The steels have to be chosen for a combination of the mechanical properties required for the torque transmission system in which they are employed and their magnetic properties for sustaining the transducer region 70 and providing a torque-dependent magnetic field component.

It has been found that such a circuit can produce a resonance which causes the coil 110 to emanate a field 50, which is detectable at some distance away. The resonance may serve to amplify the current generated in the coil. The resonance may be at a harmonic frequency related to the pulse period. The radiated field can be detected with the aid of a receiving coil 130 of say 600 turns wound on a ferrite rod. The signal has, for example, been detected on a long-wave radio using a ferrite rod aerial, that is a radio tuned in the range 150-300 kHz. The emanated field from coil 110 has been detected over a range of 30 cms up to 1.5 m.

This resonance effect has been investigated with the coil circuit shown in Fig. 6a in which the coil 110 is connected to a resonating capacitor C of 1μF in series with a resistor R of 270 Ω. The voltage across the coil is displayed in conjunction with a separate measurement of the torque acting on the transducer region. Figs. 7a, 7b and 7c are graphical displays of the detected signals for lower, medium and higher torque values respectively. The measured torque signal is the upper trace in each case, the voltage V_c across the coil is the lower trace. The coil voltage polarity is inverted which is an artifact of the instrumentation used.

The torque pulse T shows as a positive going portion T+ followed by a negative going portion T- which represents the recoil due to mechanical

energy stored in the shaft by the applied torque. The magnitude of the recoil pulse T- depends on the amount of rotation of the shaft in response to the applied torque and associated energy losses. The "torque pulse" acting on coil 110 is in the form of the torque-dependent magnetic flux generated by the transducer region 70. The coil voltage/current is primarily responsive to the rate of change of flux as already noted, that is the rate of change of the torque pulse T. It should be said that the precise nature of the torque pulse as applied to fastening a nut and bolt when the two are becoming tight is a complex subject.

The coil voltage V_c is in the nature of a double pulse, having two pulses V_1 and V_2 of opposite polarity which relate to the slope of the rising part of the applied torque pulse T and the slope of the relaxation part of the torque pulse respectively. It has been found that for torque pulses, the peak height of the coil signal is proportional to the amount of torque applied during the torque pulse. The steepness of the torque pulse slope is dependent on the initial pulse as generated, e.g. by a power torque tool, the load acting on the shaft and the shaft material, that is the elasticity of the shaft. The voltage V_c across the coil has been found to be in a range of a few to several hundred millivolts which is significant.

The teachings given above for both functions mentioned have related to investigations with the profile-shift form of longitudinal magnetisation described in WO01/96826. However, other magnetisations which produce torque-dependent magnetic fields may be treated in a similar way. Reference has already been made to circumferential-sensing longitudinal magnetisation described in WO01/13081 and circumferential or circular magnetisation in a magneto-elastic material such as disclosed in U.S. patents 5 351 555 and 5 465 627 and SAE Technical Paper Series 920707 published by the Society of Automotive Engineers under the title "Development of a Non-Contact Torque Transducer for Electric Power Steering Systems".

Circumferential magnetisation can also be used in an integral portion of a shaft. As will be decribed below the response obtained with longitudinal magnetisation of the kind described in WO01/96826 and on which the response of Fig. 4 is founded, can be utilised in a particularly beneficial way by using a two-coil sensor.

However, continuing with the single coil sensor so far discussed, its application to the adaptor of Figs. 1 and 2 will now be described. Fig. 8 shows a torque-detecting adaptor for a power torque tool such as illustrated in Fig. 2. The earlier description of Fig. 2 did not describe the sensor arrangement which coacts with transducer region 70. A coil sensor arrangement based on the teachings of Figs. 3 and 4 is shown in Fig. 8 in which the adaptor is shown in simplified form. The housing 26, which may be of enlarged radial thickness, is provided with an external groove in which the coil 110 is seated and retained to sense the field emanated by the region 70 of shaft portion 62 (Fig. 2). The coil 110 is not in contact with the shaft in the adaptor which is free to rotate within the coil. The coil should be positioned axially at a sweet spot 72a or 72b of Fig. 4. For the coil 110 to coact with region 70, the material of housing 26 (and bush 82) should not be of a magnetic material so that the coil is properly influenced by the field emanated by region 70.

An alternative is illustrated in Fig. 2 itself in which the coil indicated as 110' is embedded within the bush 82. The coil can be positioned radially close to transducer region 70 but without actually contacting the region. In order to emanate a field from the coil to communicate with the receiver unit 52 of Fig. 1, the housing 26 should be of a material that does not adversely screen the emanated field. The receiver unit 52 employs a coil wound on a ferrite rod as described with reference to Fig. 6.

To make better use of the response characteristic of Fig. 4, the modification shown in Fig. 9 is preferred. The single coil 110 is substituted by two spaced coils 110a and 110b, each aligned with a respective sweet spot 72a, 72b. The coils are connected as shown in Fig. 9a so that the resultant voltage V_c is the sum of the magnitudes of the respective coil voltages. By way of example, for a region 70 that is 22 mm wide, the sweet spots were found to be 14 to 15 mm apart. The axial centres of coils 110a, 110b were equally spaced apart, each coil being 4-5 mm long. The signal output voltage can be expected to be in the range of 0.5-1V when using 2 x 300 turn coils on a shaft of 15-18 mm diameter of FV 250B steel, the coils being terminated in a resistor R.

In accordance with the earlier discussion it is preferred to place a "resonating" capacitor, or a series CR combination, across the series connected coils as indicated in Fig. 9a. The additional component(s) are part of the adaptor and, for example, could be embedded in bush 82 as well as coils 110a and 110b.

The resultant adaptor is of rugged construction to meet the high vibration environment in which it is used and requires the minimum of components.

One problem arising out of remote signalling is that the magnitude of a received signal will be a function of distance between the transmitter and the receiver unit. The received signal level will be expected to vary as the inverse square of the distance. Thus unless the signal receiver is maintained at a fixed distance at which a calibration can be made, the magnitude of the received signal is not correlated with the torque that is being measured.

A solution to this problem is to provide the transmitted signal with its own internal reference. Fig. 10 illustrates one solution. It shows a dual polarity pulse output such as is seen in Figures 7a-7c (lower trace) representing the coil voltage V_c. One of the pulse pair is clipped to a fixed amplitude, as by a Schottky diode clipper. This is shown on the second pulse of the pair where

the clipping level is indicated at V_L. This provides a reference against which the amplitude of the first pulse of the pair is measurable.

A second solution is to use a signal, other than the torque pulse, that is generated by the torque pulse source. For example, in impact power torque tools it has been noticed that the hammer mechanism generates a signature torque signal which is separate from the desired torque impulses. This is illustrated in Fig. 11 in which the signature signal S of a constant amplitude lies between the torque pulses of varying amplitude. This provides the reference.

Claims

1. A torque transducer comprising:

a shaft subject to torque about a longitudinal axis;

a transducer element integral with or carried by the shaft and remanently magnetised to emanate a component of magnetic field that is dependent on torque applied about said axis,

a sensor coil disposed about said element to generate a voltage/current in response to changes in said component,

a load connected to said sensor coil to enable a current to circulate in the sensor coil; and

a receiver unit remote from said coil and responsive to a field emanated by said sensor coil to generate a torque-dependent signal.

2. A torque transducer as claimed in Claim 1 in which said receiver unit comprises a coil, preferably wound on a magnetic core.

3. A torque transducer as claimed in Claim 1 in which the receiver unit coil is wound on a ferrite core.

4. A torque transducer as claimed in Claim 1, 2 or 3 in which said load comprises a capacitor connected across said sensor coil to enhance a field component emanated thereby.

5. A torque transducer as claimed in any preceding claim in which said transducer element comprises a region integral with said shaft and remanently magnetised with an annulus of longitudinal magnetisation (axially-directed magnetisation) which exhibits profile shift, and said sensor coil comprises two spaced coil sections which are aligned with respective

response maxima and are connected such that the voltages induced therein are summed.

6. A torque transducer system comprises a torque transducer which is as claimed in any one of Claims 1 to 5, and wherein said shaft is coupled to or is a part of a source of a torque pulse, such as a power torque tool.

7. A torque transducer assembly comprising:

a housing having an opening therethrough;

a torque transmission shaft extending in said opening and rotatable about an axis extending through said opening, said shaft having respective end portions accessible from exteriorly of said housing,

a torque transducer element integral with, or carried by, said shaft to emanate a magnetic field dependent on the torque in the shaft,

a coil coaxial with said element and adjacent thereto; and for sensing the torque-dependent field,

a load, preferably a capacitative load, connected across the coil to enable current to circulate therethrough for emanating a field externally of the assembly that is dependent on changes in torque in the shaft.

8. A torque transducer assembly as claimed in Claim 7 in which one end portion of said shaft projects exteriorly of said housing and provides an output portion of the shaft.

9. A torque transducer assembly as claimed in Claim 7 or 8 in which said housing is configured to enable it to be secured against rotation.

10. A torque transducer assembly as claimed in Claim 9 further comprising a member having a first portion engaged with the housing and second portion

engageable with the body of a power torque tool to secure the housing against rotation with respect to said body.

11. A torque transducer comprising:

a shaft subject to torque about a longitudinal axis;

a transducer element integral with or carried by the shaft and remanently magnetised to emanate a component of magnetic field that is dependent on torque applied about said axis,

a sensor coil disposed about said element to generate a voltage/current in response to changes in said component,

a power supply unit comprising a rectifier arrangement connected to said sensor coil to derive a unipolar electrical supply from changes of torque sensed by said sensor coil; and

signalling means responsive to voltage/current signals in said sensor coil to transmit the signals in a wire-less manner for remote detection, said signalling means being powered by said electrical supply.

12. A torque transducer as claimed in Claim 11 in which said transducer element comprises a region integral with said shaft and remanently magnetised with an annulus of longitudinal magnetisation (axially-directed magnetisation) which exhibits profile shift, and said sensor coil comprises two spaced coil sections which are aligned with respective response maxima and are connected such that the voltages induced therein are summed.

13. A torque transducer comprising:

a shaft subject to torque about a longitudinal axis;

a transducer element integral with or carried by the shaft and remanently magnetised to emanate a component of magnetic field that is dependent on torque applied about said axis,

a sensor coil disposed about said element to generate a voltage/current in response to changes in said component,

a power supply unit comprising a rectifier arrangement connected to said sensor coil to derive a unipolar electrical supply from changes of torque sensed by said sensor coil;

a sensor arrangement responsive to said torque-dependent magnetic field component to provide a torque-dependent signal; and

signalling means responsive to a torque-dependent signal to transmit the signal in a wire-less manner for remote detection, said signalling means and, if appropriate, said sensor arrangement being powered by said electrical supply.

14. A torque transducer system comprises a torque transducer which is as claimed in Claim 11, 12 or 13, and wherein said shaft is coupled to or is a part of a source of a torque pulse, such as a power torque tool.

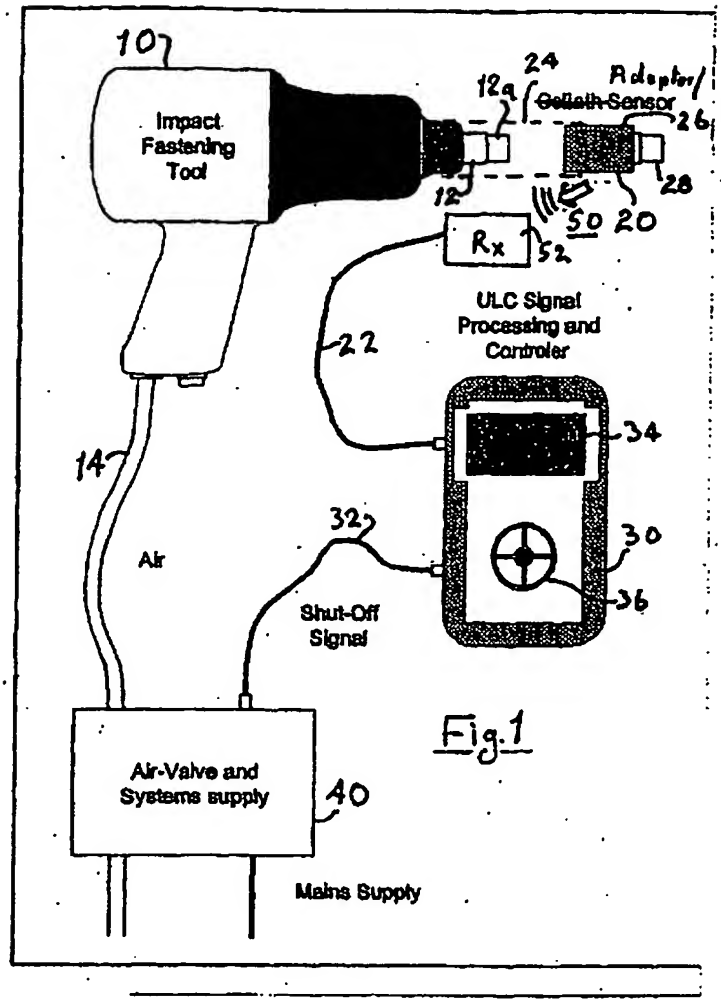
10
Impact Fastening Tool
24
12a
Adapter/
Goliath-Sensor
26
28
12
50
20
Rx
52
ULC Signal Processing and Controler
22
34
14
32
30
Air
Shut-Off Signal
36
Air-Valve and Systems supply
40
Mains Supply

Fig.1

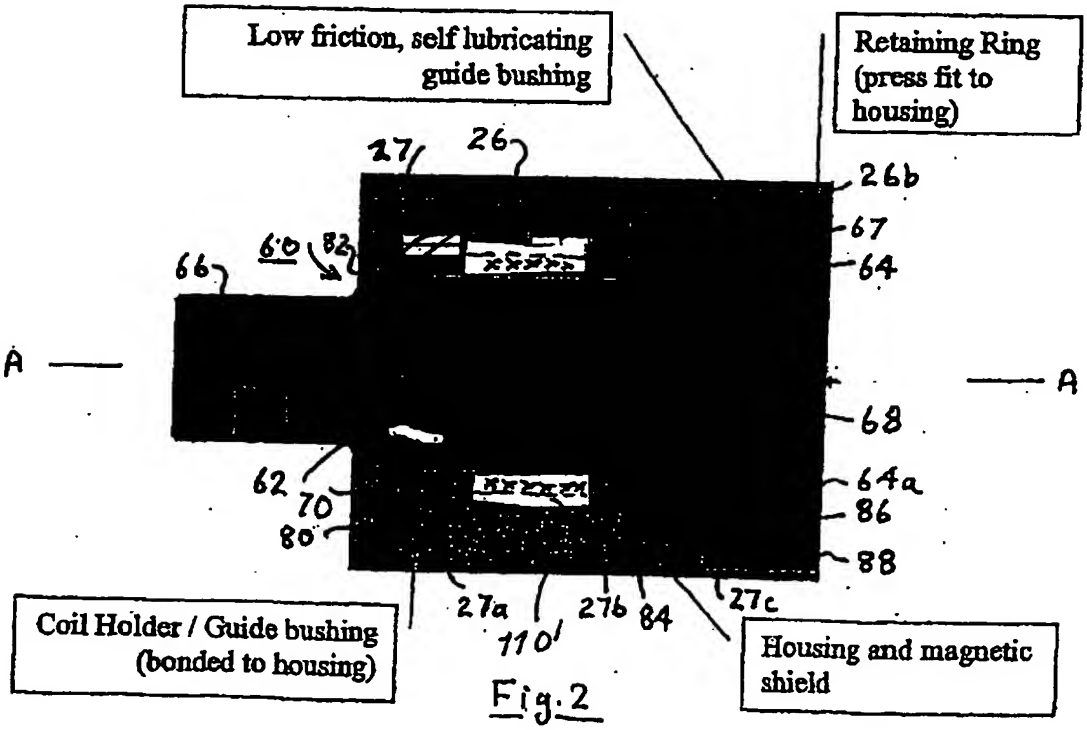
Low friction, self lubricating guide bushing
Retaining Ring (press fit to housing)
27
26
26b
67
64
60
82
66
A
A
68
62
70
80
64a
86
88
27a
110
27b
84
27c
Coil Holder / Guide bushing (bonded to housing)
Housing and magnetic shield

Fig.2

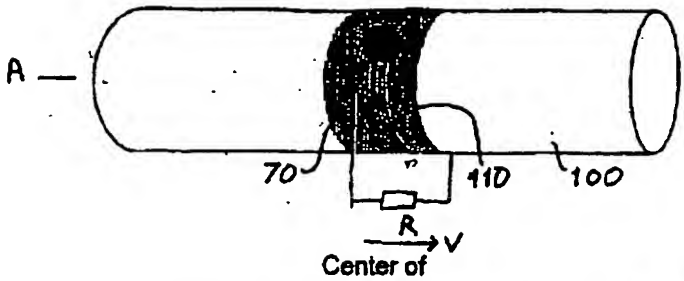

Fig. 3

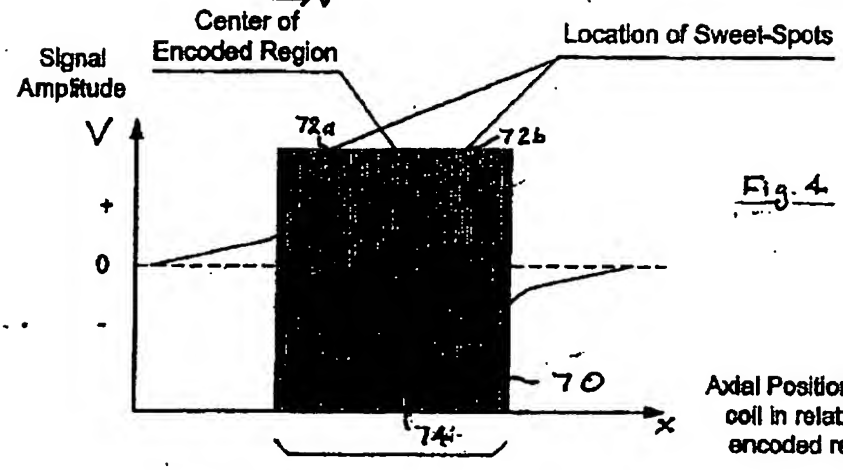

Fig. 4

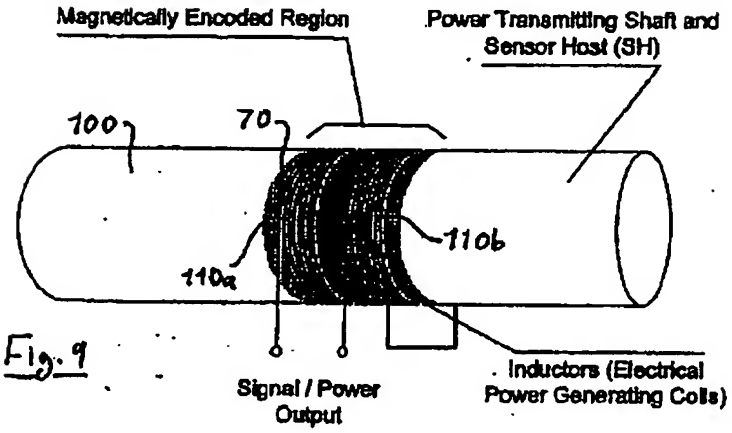

Fig. 9

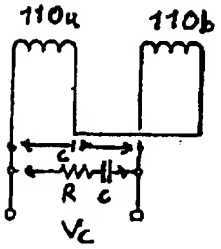

Fig. 9a

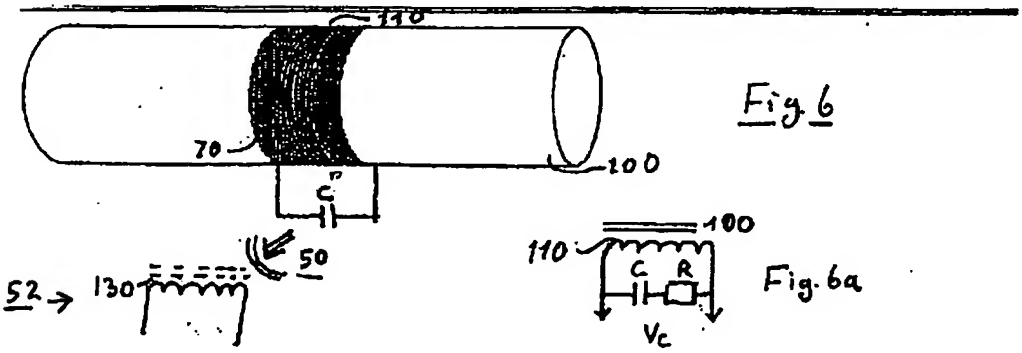

Fig. 6

Fig. 6a

while the inductor remains static.

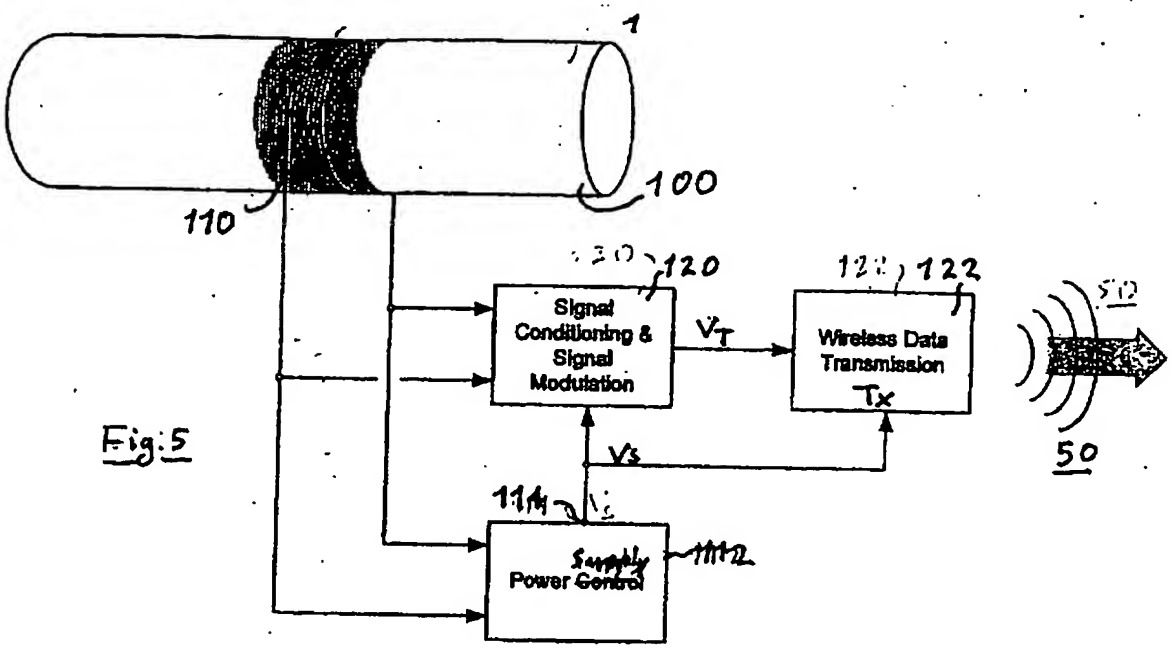

Fig:5

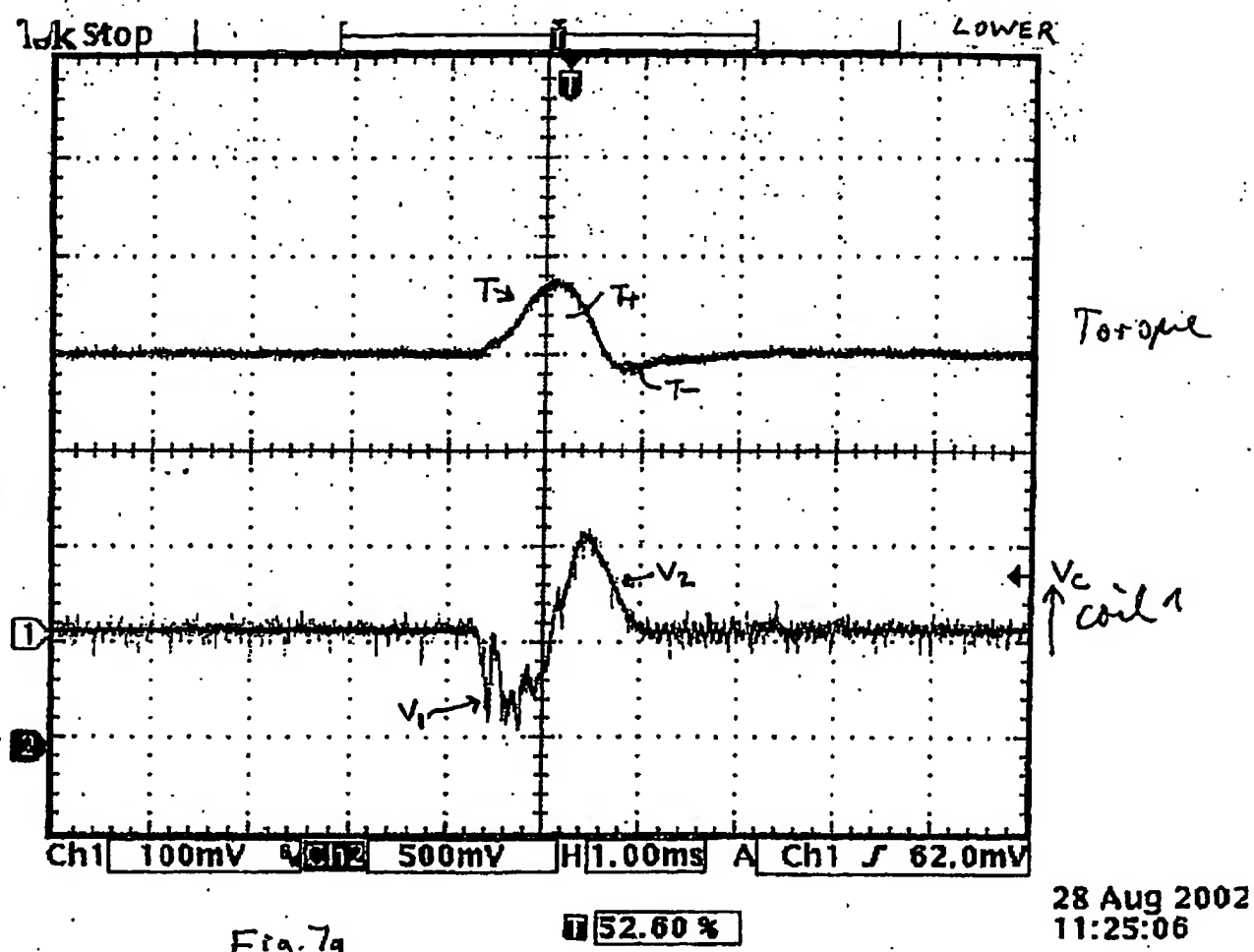
Wk Stop
LOWER
T+
T-
Torque
V2
V1
Vc
coil 1
Ch1 100mV
Ch2 500mV
H 1.00ms
A Ch1 ∫ 62.0mV
28 Aug 2002
11:25:06
T 52.60 %

Fig. 7a

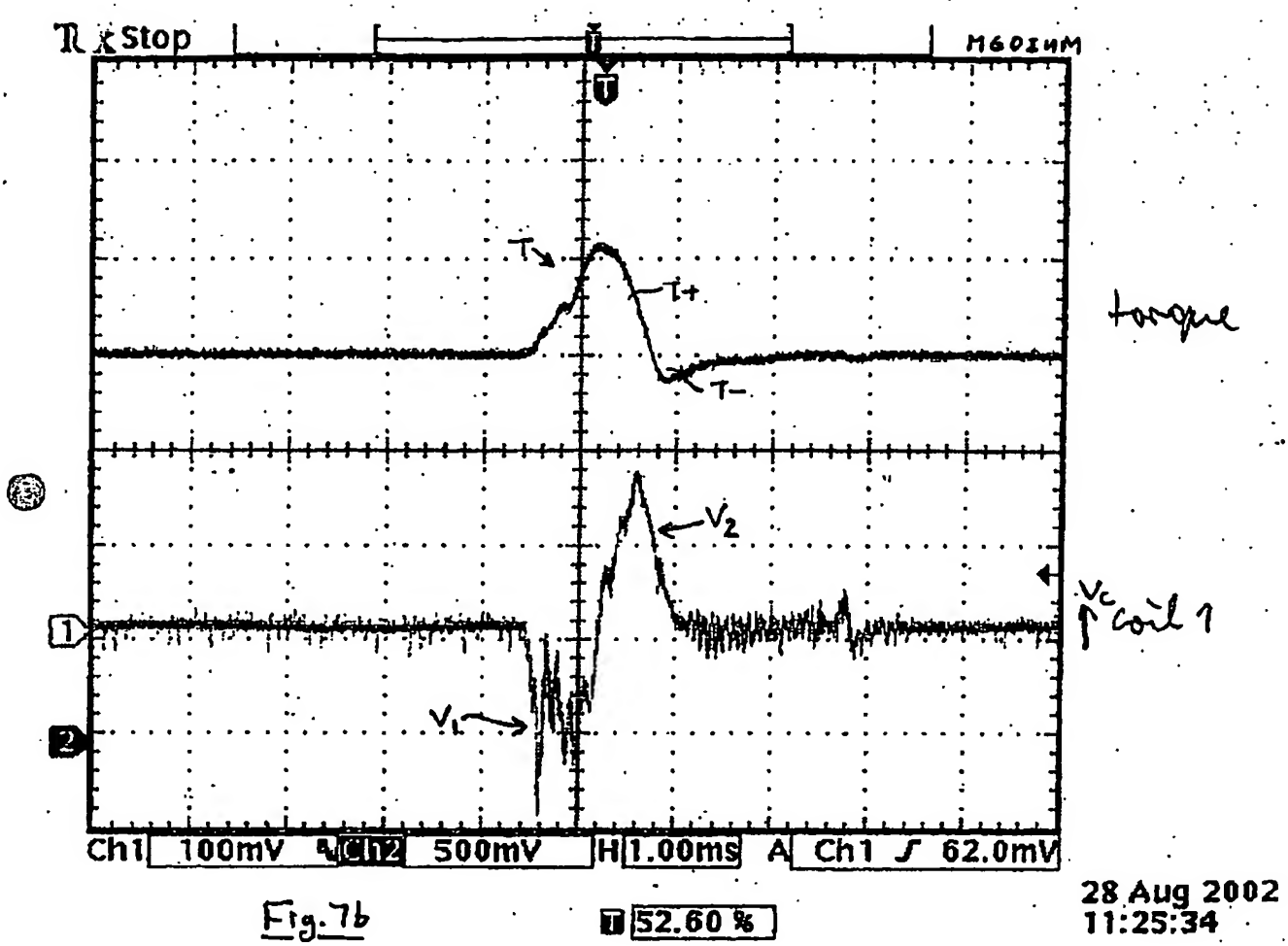
Stop
M60.1µM
T
T+
T−
torque
V2
V1
Vc coil 1
1
2
Ch1 100mV Ch2 500mV H 1.00ms A Ch1 ∫ 62.0mV
28 Aug 2002
11:25:34
52.60 %

Fig. 7b

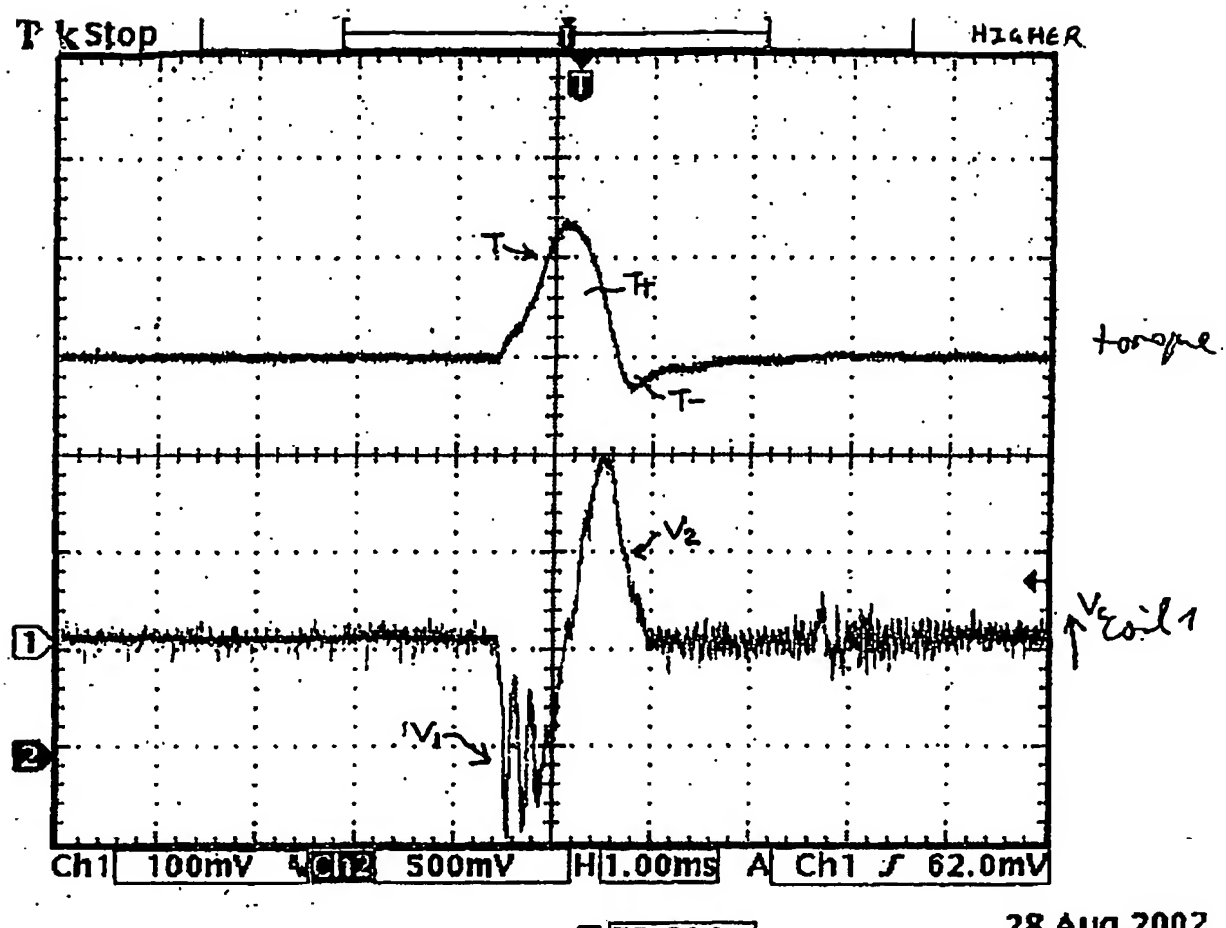
Tek Stop
HIGHER
T
Tr
T-
torque
V2
V1
V coil 1
1
2
Ch1 100mV Ch2 500mV H 1.00ms A Ch1 ∫ 62.0mV
52.60 %
28 Aug 2002
11:26:07

Fig. 7c

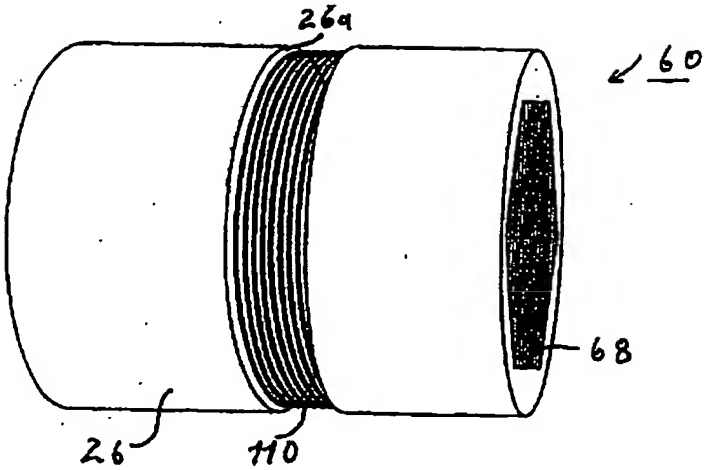

Fig.8

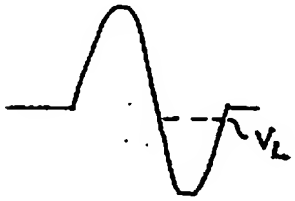

Fig.10

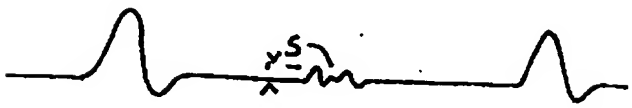

Fig.11

Docket No. 119508-00282

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Lutz Axel MAY
Serial No: Not yet assigned
Filed: March 25, 2005
For: TORQUE SIGNAL TRANSMISSION

GAU: Not yet assigned
Confirmation No. Not yet assigned
Examiner: Not yet assigned

INFORMATION DISCLOSURE STATEMENT UNDER 37 CFR 1.97

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

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Applicant(s) wish to disclose the following information.

REFERENCES

☒ The applicant(s) wish to make of record the references listed on the attached form PTO-1449. Copies of the listed references are attached, where required, as are either statements of relevancy or any readily available English translations of pertinent portions of any non-English language references.

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RELATED CASES

☐ Attached is a copy of applicant's pending application(s) or issued patent(s) which may be related to the present application. These documents are listed on form PTO-1449, also attached.

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Respectfully submitted,

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Fax (202) 572-8398
Customer No.: 27557

Date: March 25, 2005

Charles R. Wolfe, Jr.
Attorney of Record
Registration No. 28,680

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(Use as many sheets as necessary)

Sheet | 1 | of | 2

Complete if Known	
Application Number	Not yet assigned
Filing Date	March 25, 2005
First Named Inventor	Lutz Axel MAY
Art Unit	Not yet assigned
Examiner Name	Not yet assigned
Attorney Docket Number	119508-00282

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-4,882,936	11-28-1989	Ivan J. Garshelis	1-4, 6-11, 13, 14
		US-5,321,985	06-21-1994	Kashiwagi et al.	1-14

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3] Number[4] Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		EP 0 366 217 A2	05-02-1990	KABUSHIKI KAISHA TOSHIBA	5, 12 1-14	
		JP-4 286927	10-12-1992	KUBOTA CORP.	(ENGLISH ABSTRACT) 5, 12	
		JP-58-9034	01-19-1983	HARADA KOSUKE SASADA ICHIRO	(ENGLISH ABSTRACT) 1, 7, 11, 13	

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Sheet	2	of	2

Complete if Known	
Application Number	Not yet received
Filing Date	March 25, 2005
First Named Inventor	Lutz Axel MAY
Art Unit	Not yet assigned
Examiner Name	Not yet assigned
Attorney Docket Number	119508-00282

NON PATENT LITERATURE DOCUMENTS

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		Notification Concerning submission Or Transmittal Of Priority Document , date stamped Jan. 13, 2004.	
		Notification Of Transmittal Of The International Preliminary Examination Report, date stamped Dec. 6, 2004.	
		Copy of International Application No. PCT/EP2003/010634 , International filing date September 24, 2003 (PCT W0 2004/029569 A1) International Publication Date April 8, 2004.	

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D1

United States Patent [19]

Garshelis

[11] Patent Number: 4,882,936

[45] Date of Patent: Nov. 28, 1989

[54] MAGNETOELASTIC TORQUE TOOL

[75] Inventor: Ivan J. Garshelis, Cheshire, Mass.

[73] Assignee: Mag Dev Inc., Pittsfield, Mass.

[21] Appl. No.: 95,774

[22] Filed: Sep. 14, 1987

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 938,404, Dec. 5, 1986, Pat. No. 4,760,745.

[51] Int. Cl.[4] G01L 3/10

[52] U.S. Cl. 73/862.36

[58] Field of Search ..... 73/862.36, 862.21, DIG. 2; 324/209; 81/467

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(List continued on next page.)

Primary Examiner—Jerry W. Myracle

Attorney, Agent, or Firm—Sixbey, Friedman, Leedom & Ferguson

[57] ABSTRACT

A hand tool for applying torque to a fastener includes a portion for engaging the fastener, a handle to which torque is hand-applied and a torque carrying member operatively coupled with the handle and the fastener-engaging portion for transmitting the hand-applied torque to the fastener. The torque carrying member includes a magnetoelastic torque transducer comprising a ferromagnetic, magnetostrictive region affixed to, associated with or forming a part of the surface of the torqued member for altering in magnetic premeability in response to the application of torque to the member. Additionally, the transducer includes a magnetic source for applying a cyclically time varying magnetic field to the ferromagnetic, magnetostrictive region for sensing the change in permeability caused by the applied torque, apparatus/circuitry for converting the sensed change in permeability to an electrical signal indicative of the magnitude of the torque applied to the member and an indicator responsive to the electrical signal for providing an indication that a predetermined torque has been applied to the fastener. The ferromagnetic, magnetostrictive region is advantageously formed of nickel maraging steel, desirably 18% Ni maraging steel. Preferably, the transducer comprises a pair of axially spaced-apart annular bands defined within the ferromagnetic, magnetostrictive region, the bands being endowed with residual stress created, respectively symmetrical right and left hand helically directed magnetic anisotropy of sufficiently large magnitude that the contribution to total magnetic anistropy of any random anisotropy in the member is negligible.

30 Claims, 8 Drawing Sheets

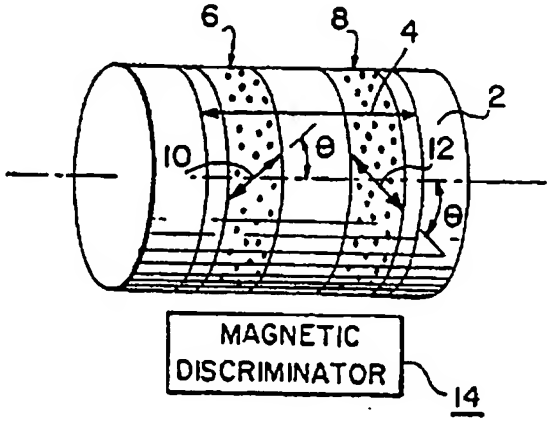

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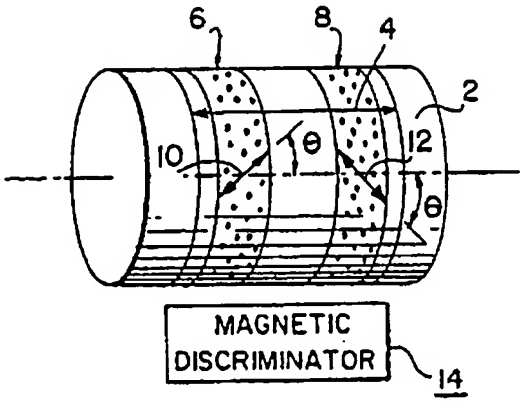
FIG. 1.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MAGNETIC DISCRIMINATOR
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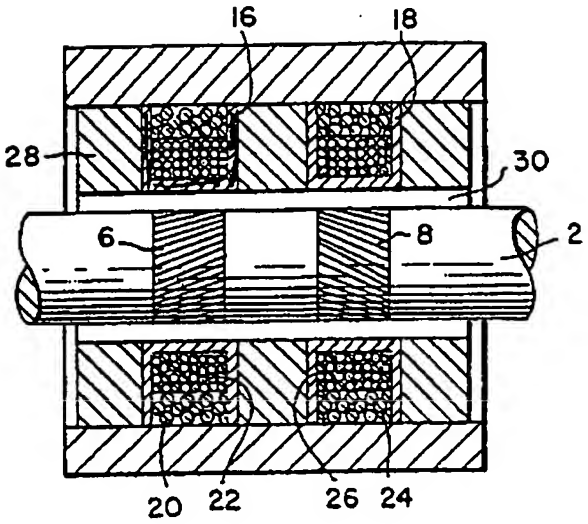
FIG. 2.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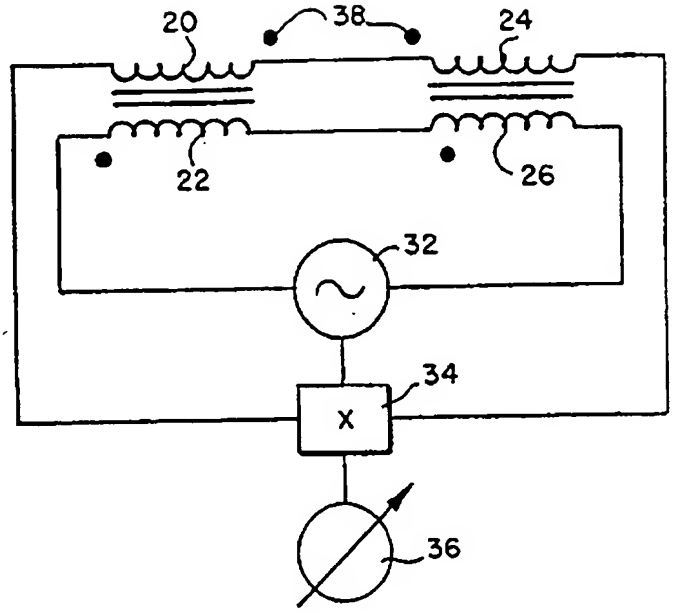
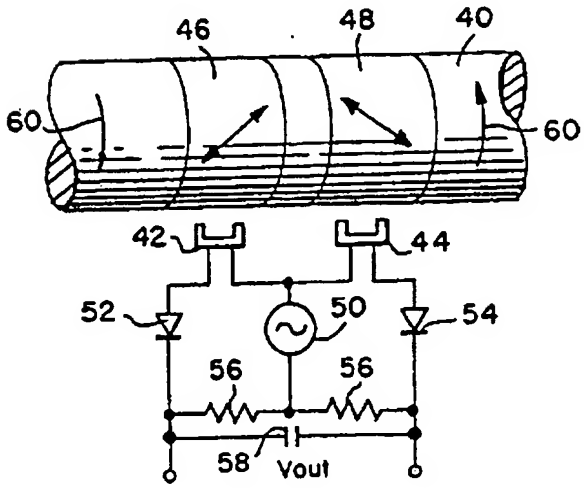


FIG. 4.



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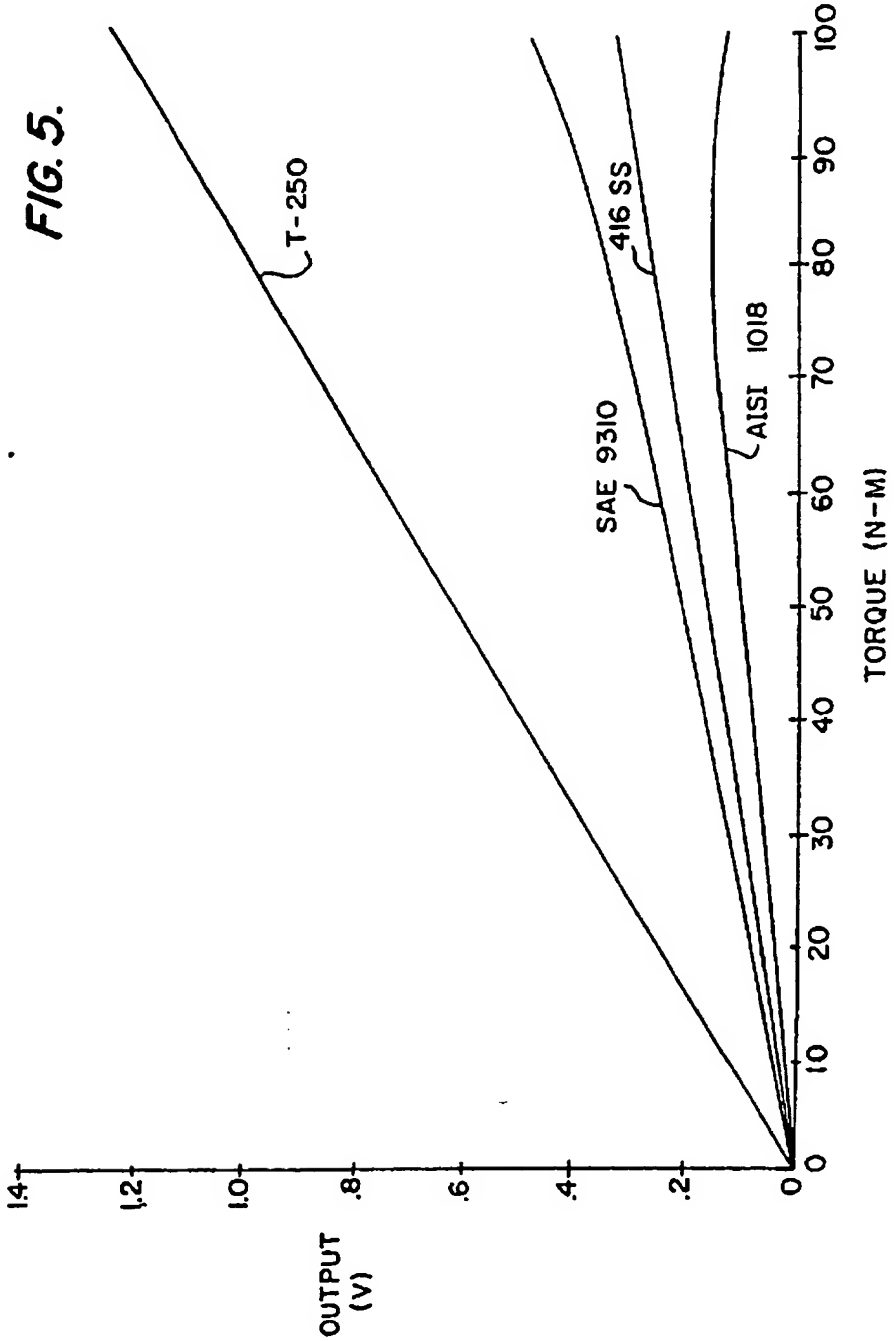
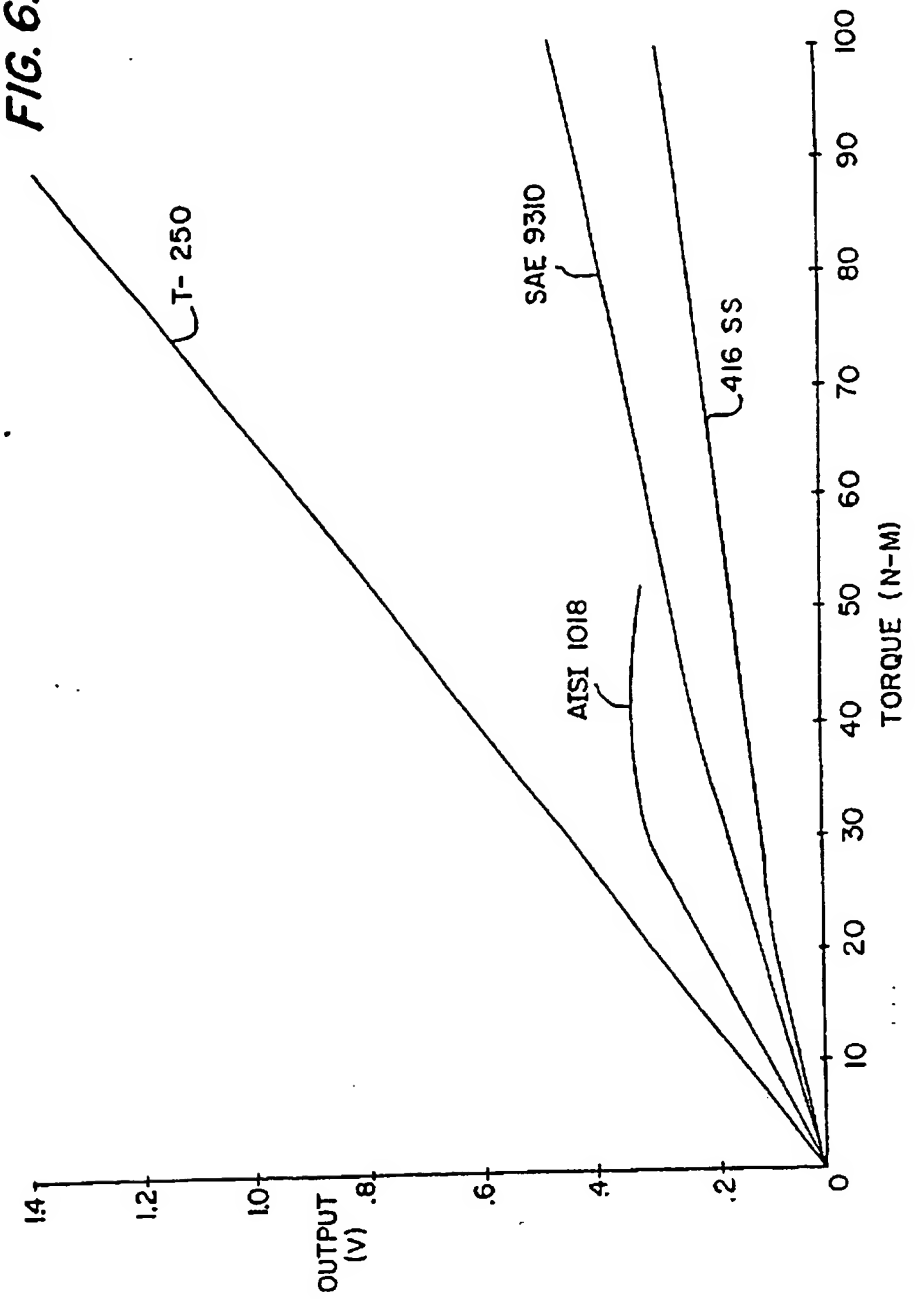


FIG. 6.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AISI 1018
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TORQUE (N-M)

FIG. 7.

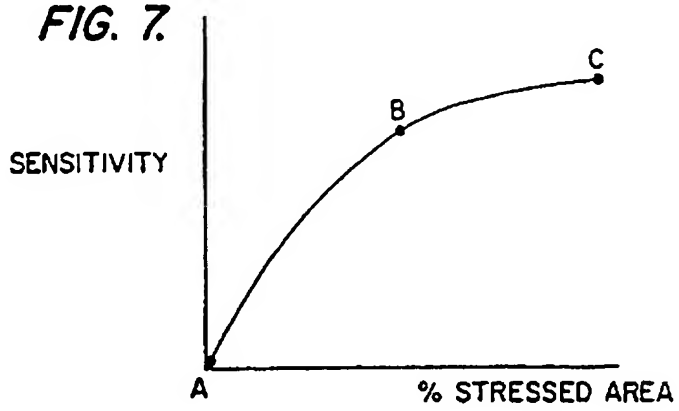


FIG. 8.

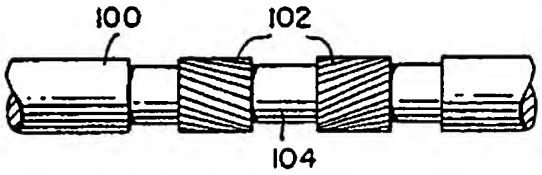
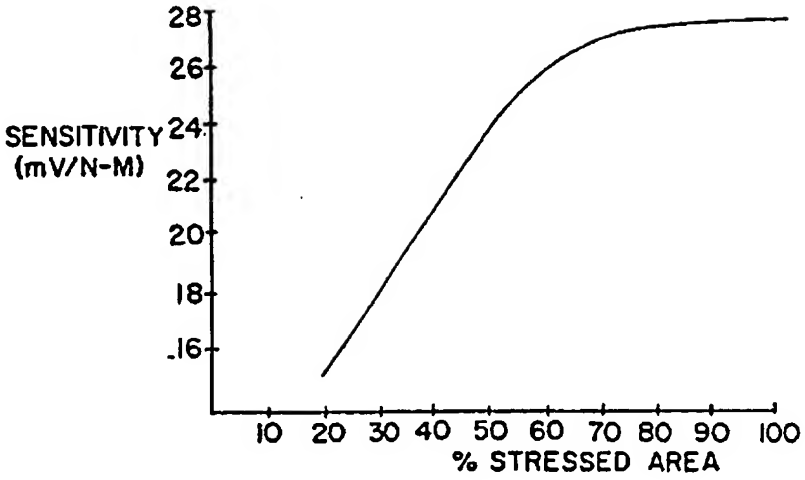


FIG. 9.



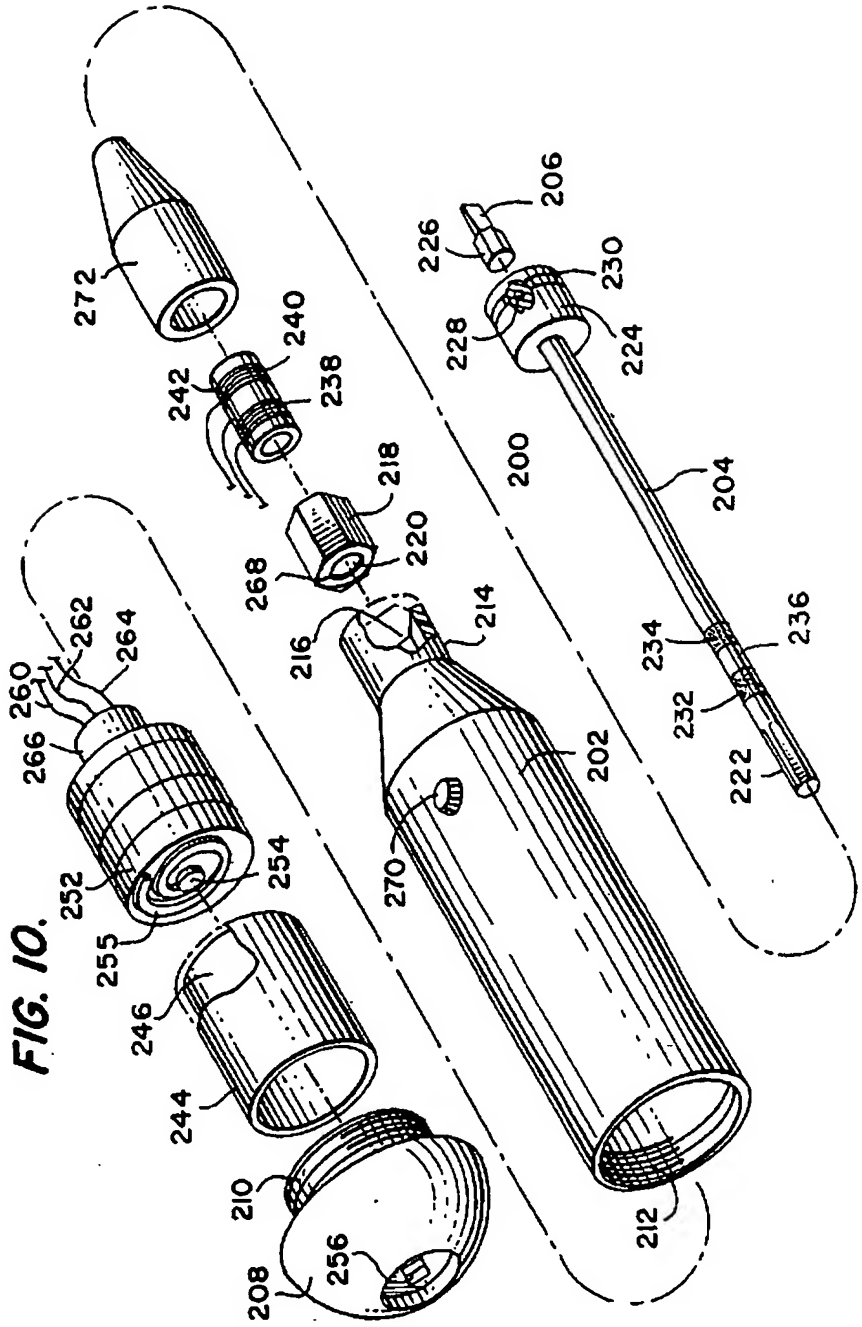

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FIG. 10.

FIG. 11.

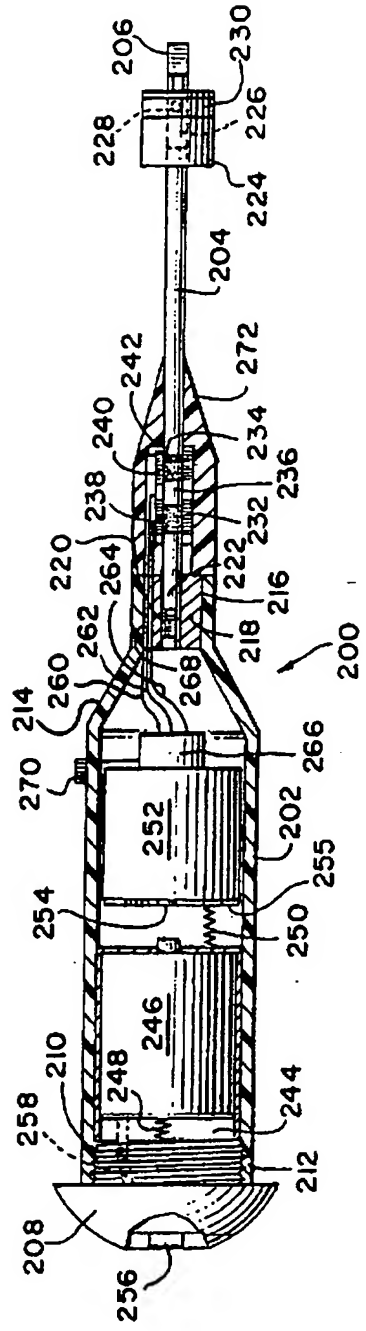
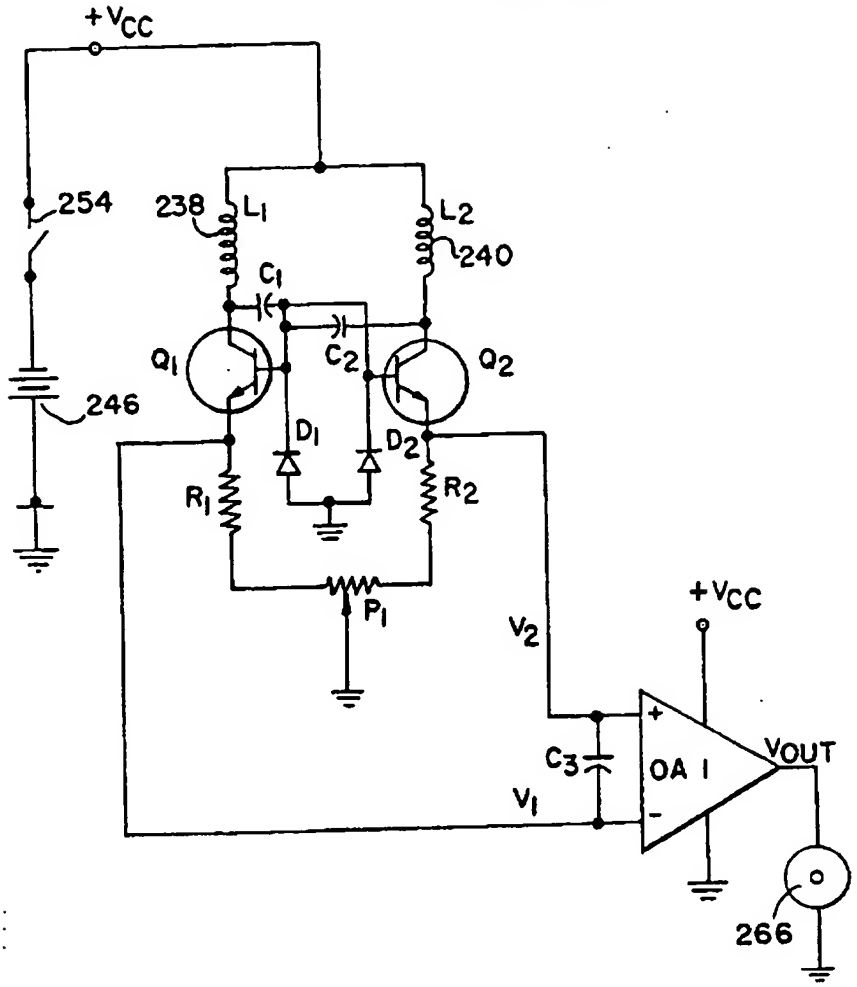


FIG. 12.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C3
OA 1
VOUT
V1
266

MAGNETOELASTIC TORQUE TOOL

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. application Ser. No. 938,404, filed December 5, 1986, now U.S. Pat. No. 4,760,745.

TECHNICAL FIELD

The present invention relates to torque sensors and, more particularly, to non-contacting magnetoelastic torque transducers for providing a measure of the torque applied to a rotary shaft.

BACKGROUND ART

In the control of systems having rotating drive shafts, it is generally recognized that torque is a fundamental parameter of interest. Therefore, the sensing and measurement of torque in an accurate, reliable and inexpensive manner has been a primary objective of workers for several decades. Although great strides have been made, there remains a compelling need for inexpensive torque sensing devices which are capable of continuous torque measurements over extended periods of time despite severe environments.

All magnetoelastic torque transducers have two features in common—(1) a torqued member which is ferromagnetic and magnetostrictive, the former to ensure the existence of magnetic domains and the latter to allow the orientation of the magnetization within each domain to be altered by the stress associated with applied torque; and (2) a means, most usually but not necessarily electromagnetic means, for sensing variations from the untorqued distribution of domain orientations. The differences among the various existing or proposed magnetoelastic torque transducers lie in the detailed variations of these common features.

It is well known that the permeability of magnetic materials changes due to applied stress. When a torsional stress is applied to a cylindrical shaft of magnetostrictive material, each element in the shaft is subjected to a shearing stress. This shearing stress may be expressed in terms of a tensile stress and an equal and perpendicular compressive stress with the magnitude of each stress being directly proportional to the distance between the shaft axis and the element. The directions of maximum tension and compression occur along tangents to 45° left-handed and 45° right-handed helices about the axis of the shaft. The effect of the torque is to increase the magnetic permeability in directions parallel to one of the helices and, correspondingly, to decrease the magnetic permeability in directions parallel to the other of the helices. In their article "Magnetic Measurements of Torque in a Rotating Shaft", The Review of Scientific Instruments, Vol. 25, No. 6, June, 1954, Beth and Meeks suggest that in order to use permeability change as a measure of the applied torque, one should monitor permeability along the principal stress directions and pass the magnetic flux through the shaft near its surface. This is because the stress is greater, the further the element is from the shaft axis and it is along the principal stress directions that the maximum permeability change is expected. To accomplish this, Beth and Meeks used a yoke carrying a driving coil for producing an alternating flux in the shaft and pickup coils on each of several branches to detect the permeability changes caused by the applied torque in flux paths lying in or

near the principal stress directions in the shaft. When the shaft is subjected to a torque, the mechanical stresses attributable to torque resolve into mutually perpendicular compressive and tensile stresses which cause the permeability in the shaft to increase in the direction of one stress and decrease in the direction of the other. As a result, the voltage induced in the pickup or measuring coils increases or decreases. The difference in magnitude of the induced voltages is proportional to the torsional stress applied to the shaft. A similar approach was taken in U.S. Pat. No. 3,011,340—Dahle. The principal shortcoming in these type devices is the need to accomplish permeability sensing along the principal stress directions with its attendant disadvantages, such as its sensitivity to variations in radial distance from the shaft, magnetic inhomogeneity around the shaft circumference and non-compensatable dependence on shaft speed. As a result, devices such as these have only found applications on large diameter shafts, i.e., 6-inches and larger, but have not been found to be adaptable to smaller shafts where the vast majority of applications exist.

It was felt by some that devices such as were taught in Beth and Meeks and U.S. Pat. No. 3,011,340—Dahle, wherein the rotating shaft itself acted as the magnetic element in the transducer, had significant drawbacks in practical application. This is because the materials and metallurgical processing which may have been used to impart the desired mechanical properties to the shaft for its desired field of use will, in most cases, not be optimum or even desirable for the magnetic qualities required in a magnetoelastic torque sensor. The random anisotropy in a shaft created during its manufacture, due to internal stresses and/or resulting from regions of differing crystal orientation will cause localized variations in the magnetic permeability of the shaft which will distort the desired correlation between voltage sensed and applied torque. The solution, according to U.S. Pat. No. 3,340,729—Scoppe is to rigidly affix, as by welding, a magnetic sleeve to the load-carrying shaft so that a torsional strain proportional to the torsional load is imparted to the sleeve. The measuring device employed now senses permeability changes in the rotating sleeve rather than in the rotating shaft. This permits, according to Scoppe, a material to be selected for the shaft which optimizes the mechanical and strength properties required for the shaft while a different material may be selected for the sleeve which optimizes its magnetic properties. As with prior art devices, the Scoppe torquemeter utilized a primary winding for generating a magnetic flux and two secondary windings, one oriented in the tension direction and the other in the compression direction. Although obviating at least some of the materials problems presented by Dahle, the use of a rigidly affixed sleeve creates other, equally perplexing problems. For example, the task of fabricating and attaching the sleeve is a formidable one and even when the attachment means is welding, which eliminates the bond strength problem, there remains the very significant problem that the coefficient of thermal expansion of the steel shaft is different (in some cases up to as much as 50% greater) than the corresponding coefficient of any magnetic material selected for the sleeve. A high temperature affixing process, such as welding, followed by cooling establishes stresses in the magnetic material which alters the resultant magnetic anisotropy in an uncontrolled manner. Moreover, an-

nealing the shaft and sleeve to remove these stresses also anneals away desirable mechanical properties in the shaft and changes the magnetic properties of the sleeve. Furthermore, like the Dahle device, the shortcomings of Scoppe's transducer, due to its need to monitor permeability changes lying along the principal stress directions, are its sensitivity to variations in its radial distance from the shaft, magnetic inhomogeneity around the shaft circumference and dependence on shaft speed.

A different approach to magnetoelastic torque sensing utilizes the differential magnetic response of two sets of amorphous magnetoelastic elements adhesively attached to the torqued shaft. This approach has the advantage over prior approaches that it is insensitive to rotational position and shaft speed. However, it requires inordinate care in the preparation and attachment of the elements. Moreover, transducer performance is adversely affected by the methods used to conform the ribbon elements to the shape of the torqued member; the properties of the adhesive, e.g., shrinkage during cure, expansion coefficient, creep with time and temperature under sustained load; and, the functional properties of the amorphous material itself, e.g., consistency, stability. Still another concern is in the compatibility of the adhesive with the environment in which the transducer is to function, e.g., the effect of oil, water, or other solvents or lubricants on the properties of the adhesive.

In the article "A New Torque Transducer Using Stress Sensitive Amorphous Ribbons", IEEE Trans. on Mag., MAG-18, No. 6, 1767–9, 1982, Harada et al. disclose a torque transducer formed by gluing two circumferential stress-sensitive amorphous ribbons to a shaft at axially spaced apart locations. Unidirectional magnetoelastic magnetic anisotropy is created in each ribbon by torquing the shaft in a first direction before gluing a first ribbon to it, releasing the torque to set-up stresses within the first ribbon, torquing the shaft in the opposite direction, gluing the second ribbon to it, and then releasing the torque to set-up stresses within the second ribbon. The result is that the anisotropy in one ribbon lies along a right-hand helix at +45° to the shaft axis while the anisotropy in the other ribbon lies along an axially symmetric left-hand helix at −45° to the shaft axis. AC powered excitation coils and sensing coils surround the shaft making the transducer circularly symmetric and inherently free from fluctuation in output signal due to rotation of the shaft. In the absence of torque, the magnetization within the two ribbons will respond symmetrically to equal axial magnetizing forces and the sensing coils will detect no difference in the response of the ribbons. However, when torque is applied, the resulting stress anisotropy along the principal axes arising from the torque combines asymmetrically with the quiescent anisotropies previously created in the ribbons and there is then a differing response of the two ribbons to equal axial magnetizing force. This differential response is a function of the torque and the sensing coils and associated circuitry provide an output signal which is proportional to the applied torque. Utilizing substantially the same approach, in Japanese patent publication No. 58-9034, two amorphous ribbons are glued to a shaft and symmetrical magnetic anisotropy is given to the ribbons by heat treatment in a magnetic field at predetermined equal and opposite angles. Amorphous ribbons have also been glued to a shaft in a ±45° chevron pattern, see Sasada et al., IEEE Trans. on Mag., MAG-20, No. 5, 951–53, 1984, and amorphous ribbons containing parallel slits aligned with the ±45° directions have been glued to a shaft, see, Mohri, IEEE Trans. on Mag., MAG-20, No. 5, 942–47, 1984, to create shape magnetic anisotropy in the ribbons rather than magnetic anisotropy due to residual stresses. Other recent developments relevant to the use of adhesively attached amorphous ribbons in a magnetoelastic torque transducer are disclosed in U.S. Pat. No. 4,414,855—Iwasaki and U.S. Pat. No. 4,598,595—Vranish et al.

More recently, in apparent recognition of the severe shortcomings inherent in using adhesively affixed ribbons, plasma spraying and electrodeposition of metals over appropriate masking have been utilized. See: Yamasaki et al, "Torque Sensors Using Wire Explosion Magnetostrictive Alloy Layers", IEEE Trans. on Mag., MAG-22, No. 5, 403–405 (1986); Sasada et al, "Noncontact Torque Sensors Using Magnetic Heads and Magnetostrictive Layer on the Shaft Surface—Application of Plasma Jet Spraying Process", IEEE Trans. on Mag., MAG-22, No. 5, 406–408 (1986).

The hereinbefore described work with amorphous ribbons was not the first appreciation that axially spaced-apart circumferential bands endowed with symmetrical, helically directed magnetic anisotropy contributed to an improved torque transducer. USSR Certificate No. 667,836 discloses a magnetoelastic torque transducer having two axially spaced-apart circumferential bands on a shaft, the bands being defined by a plurality of slots formed in the shaft in a ±45° chevron pattern, and a pair of excitation and measuring coil-mounting circumferential bobbins axially located along the shaft so that a band underlies each bobbin. The shape anisotropy created by the slots is the same type of magnetic preconditioning of the shaft as was created, for example, by the chevron-patterned amorphous ribbons of Sasada et al and the slitted amorphous ribbons of Mohri, and suffers from many of the same shortcomings. USSR Certificate No. 838,448 also discloses a magnetoelastic torque transducer having two spaced-apart circumferential bands on a shaft, circumferential excitation coils and circumferential measuring coils surrounding and overlying the bands. In this transducer the bands are formed by creating a knurl in the shaft surface with the troughs of the knurl at ±45° angles to the shaft axis so that the troughs in one band are orthogonal to the troughs in the other band. The knurls are carefully formed by a method which ensures the presence of substantial unstressed surface sections between adjacent troughs so that the magnetic permeability of the troughs is different from the magnetic permeability of the unstressed areas therebetween. Inasmuch as the trough width-to-pitch ratio corresponds to the stressed to unstressed area ratio and the desired ratio appears to be 0.3, there is no circumferential region in either band which is intentionally stressed over more than 30% of its circumferential length. This very minimal stress anisotropic preconditioning is believed to be too small to provide a consistent transducer sensitivity, as measured by the electronic signal output of the measuring coils and their associated circuitry, for economical commercial utilization.

Notwithstanding their many shortcomings in forming sensitive and practical bands of magnetic anisotropy on a torqued shaft, the efforts evidenced in the Harada et al, Sasada et al, Mohri and Yamasaki et al articles and the USSR certificates represent significant advances over the earlier work of Beth and Meeks, Dahle and Scoppe in recognizing that a pair of axially spaced-

apart, circumferential bands of symmetrical, helically directed anisotropy permits averaging axial permeability differences over the entire circumferential surface. This is notably simpler than attempting to average helical permeability differences sensed along the principal stress axes, as had earlier been suggested. Moreover, neither rotational velocity nor radial eccentricity significantly influence the permeability sensed in this manner. Nevertheless, these efforts to perfect means of attachment of magnetoelastically optimized material to the surface of the torqued member introduces unacceptable limitations in the resulting torque sensor. The application to the shaft of adhesively affixed amorphous ribbons suffers from significant drawbacks, such as the methods used to conform the ribbons to the shaft, the properties of the adhesive and the functional properties of the amorphous material, which make such ribbons impractical for commerical implementation. The use of rigidly affixed sleeves as taught by Scoppe and, more recently, in U.S. Pat. No. 4,506,554—Blomkvist et al, is unsuitable for practical applications due to the higher costs involved as well as the stresses created by high temperature welding and/or the uncertainties in magnetic and mechanical properties created by subsequent annealing. Likewise, reliance upon shape anisotropy or predominantly unstressed regions to create stress anisotropy present significant problems which make such techniques impractical for commercial implementation.

It is, therefore, apparent that despite the many advances in torque transducer technology, there still exists a need for a magnetoelastic torque transducer which is significantly more economical than previous torque transducers, allowing use in many applications for which such transducers were not heretofore either economically or environmentally viable, and which is applicable to small as well as large diameter shafts, whether stationary or rotating at any practical speed.

DISCLOSURE OF THE INVENTION

In accordance with one broad aspect of the present invention there is provided a magnetoelastic torque transducer for providing an electrical signal indicative of the torque applied to a member in which a ferromagnetic and magnetostrictive region of the torqued member serves as a part of the magnetic sensing circuit of the transducer by providing at the surface of said region a pair of axially spaced-apart annular bands endowed with residual stress created, respectively symmetrical, left and right hand helically directed magnetic anisotropy of relatively large magnitude, which anisotropy overwhelms and/or renders negligible or insignificant any random anisotropy in the member as a result of internal stresses due to mechanical working, inhomogeneities, crystal orientation, and the like.

In accordance with another aspect of the present invention, there is provided a magnetoelastic torque transducer for providing an electrical signal indicative of the torque applied to a member, said member having a ferromagnetic and magnetostrictive region, said transducer comprising a pair of axially spaced-apart annular bands defined within said region, said bands having, at least at the surface of said member, respectively symmetrical right and left hand helically directed residual stress created magnetic anisotropy, each said band having at least one circumferential region which is free of residually unstressed areas, i.e., said at least one circumferential region is residually stressed, over at least 50% of its circumferential length; means for applying an alternating magnetic field to said bands; means for sensing the change in permeability of said bands caused by said applied torque; and means for converting said sensed change in permeability to an electrical signal indicative of the magnitude of the torque applied to said member. In a preferred aspect, the ferromagnetic and magnetostrictive region is formed of nickel maraging steel.

In accordance with another aspect, the present invention contemplates a magnetoelastic torque transducer for providing an electrical signal indicative of the torque applied to a member, including ferromagnetic, magnetostrictive means rigidly affixed to, associated with or forming a part of the surface of said torqued member for altering in magnetic permeability in response to the application of torque to said member, means for applying a magnetic field to said ferromagnetic, magnetostrictive means, means for sensing the change in permeability caused by said applied torque and means for converting said sensed change in permeability to an electrical signal indicative of the magnitude of the torque applied to said member, the ferromagnetic, magnetostrictive means being formed from nickel maraging steel.

In still another aspect of the present invention, there is provided a method of sensing the torque applied to a member having a ferromagnetic and magnetostrictive region, which includes the steps of endowing a pair of axially spaced-apart annular bands within said region with respectively symmetrical, right and left hand helically directed magnetic anisotropy, applying an alternating magnetic field to said bands and sensing the permeability difference between said bands resulting from the application of torque to said member, the difference being indicative of the magnitude of the applied torque, the improvement which comprises forming said bands at the surface of said member and endowing said bands with magnetic anisotropy by instilling a residual stress distribution in each band which is sufficiently extensive that at least one circumferential region within each band is free of residually unstressed areas, i.e., said at least one circumferential region is residually stressed, over at least 50% of its circumferential length. In a preferred aspect of this method, the ferromagnetic and magnetostrictive region is formed from nickel maraging steel.

In yet another aspect of the invention, there is provided a method of sensing the torque applied to a member having a ferromagnetic and magnetostrictive region which includes the steps of endowing said region with helically directed magnetic anisotropy by instilling a residual stress distribution in said region which is sufficiently extensive that at least one circumferential region within said ferromagnetic and magnetostrictive region is free of residually unstressed areas, i.e., said at least one circumferential region is residually stressed, over at least 50% of its circumferential length, applying an alternating magnetic field to said ferromagnetic and magnetostrictive region and to an area of said member not so endowed, and sensing the permeability difference between said ferromagnetic and magnetostrictive region and said area resulting from the application of torque to said member, the difference being indicative of the magnitude of the applied torque. In a preferred aspect of this method, the ferromagnetic and magnetostrictive region is formed from nickel maraging steel.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view of a magnetoelastic torque transducer in accordance with the present invention;

FIG. 2 is a sectional view of a magnetoelastic torque transducer in accordance with the present invention illustrating one form of magnetic discriminator useful therewith;

FIG. 3 is a circuit diagram showing the circuitry associated with the magnetic discriminator of FIG. 2;

FIG. 4 is a schematic view of a magnetoelastic torque transducer in accordance with the present invention illustrating another form of magnetic discriminator, and its associated circuitry, useful therewith;

FIG. 5 is a graphical representation of the relationship between applied torque and output signal for several magnetoelastic torque transducers of the present invention;

FIG. 6 is a graphical representation of the relationship between applied torque and output signal for the magnetoelastic torque transducers of FIG. 5 after the shafts thereof have been heat treated under identical conditions;

FIG. 7 is a graphical representation of the general relationship between torque transducer sensitivity and residual stress loading along the circumferential length of a circumferential region of the bands of a transducer of the present invention;

FIG. 8 is an elevational view of a test piece used in torque transducer sensitivity testing;

FIG. 9 is a graphical illustration, as in FIG. 7, of the sensitivity vs. residual stress loading relationship for a transducer of the present invention wherein the bands thereof were endowed with residual stress induced magnetic anisotropy by a controlled knurling technique;

FIG. 10 is an exploded view, partially broken away, of one form of torque tool in accordance with the present invention;

FIG. 11 is an elevational view of the torque tool of FIG. 10; and

FIG. 12 is a circuit diagram of a multivibrator and indicator circuit useful in the torque tool of FIG. 10.

BEST MODE FOR CARRYING OUT THE INVENTION

In accordance with the present invention there is provided a magnetoelastic torque transducer comprising (1) a torque carrying member at least the surface of which, in at least one complete circumferential region of suitable axial extent, is appropriately ferromagnetic and magnetostrictive; (2) two axially distinct circumferential bands within this region or one such band in each of two such regions that are endowed with respectively symmetrical, helically directed residual stress induced magnetic anisotropy such that, in the absence of torque, the magnetization tends to be oriented along a left-hand (LH) helix in one band and along an axially symmetrical right-hand (RH) helix in the other band; and (3) a magnetic discriminator device for detecting, without contacting the torqued member, differences in the response of the two bands to equal, axial magnetizing forces.

These features of the magnetoelastic torque transducer of the present invention will be better understood by reference to FIG. 1 in which a cylindrical shaft 2 formed of ferromagnetic and magnetostrictive material or, at least having a ferromagnetic and magnetostrictive region 4, is illustrated having a pair of axially spaced-apart circumferential or annular bands 6,8 endowed with respectively symmetrical, helically directed magnetic stress anisotropy in the angular directions $\pm\theta$ of the respective magnetic easy axes 10,12. A magnetic discriminator 14 is spaced from shaft 2 by a small radial space. In the absence of applied torque the magnetization within the bands 6,8 will respond symmetrically to the application of equal axial magnetizing forces. Longitudinal or axial components of the magnetization within these two bands remain identical, since $\cos\theta = \cos-(\theta)$ for all values of θ, and the magnetic discriminator will therefore, detect no difference or zero. With the application of torque to shaft 2, the stress anisotropy arising therefrom combines asymmetrically with the quiescent anisotropies intentionally instilled in the bands and there is then a differing response of the two bands to equal axial magnetizing force. Since the stress anisotropy is a function of the direction and magnitude of the torque, the differential response of the two bands will be a monotonic function of the torque. The resulting differences in magnetic anisotropy in each of the bands is evidenced by the axial permeability of one band increasing and that of the other band decreasing. The difference in axial permeabilities of the two bands is used to sense the torque. A properly designed magnetic discriminator will detect detailed features of the differential response and provide an output signal that is an analog of the torque.

In accordance with the present invention, the torque carrying member is provided with two axially spaced-apart, distinct circumferential or annular bands in the ferromagnetic region of the member. There are no particular geometric, space, location or circumferential limitations on these bands, save only that they should be located on the same diameter member and close enough to one another to experience the same torque. The bands are intentionally endowed with respective symmetrical, helically directed, magnetic anisotropy caused by residual stress. Residual stress may be induced in a member in many different ways, as discussed more fully hereinbelow. However, all techniques have in common that they apply stress to the member beyond the elastic limit of at least its surface region such that, when the applied stress is released, the member is unable to elastically return to an unstressed condition. Rather, residual stresses remain which, as is well known, give rise to magnetic anisotropy. Depending upon the technique utilized for applying stress, the angular direction of the tangential principal residual stress with the member's axis will vary between values greater than zero and less than 90°. Preferably, the angular direction of the residual stress and that of the resulting magnetic easy axes, is from 10°–80° and, most desirably, from 20°–60°.

It will be appreciated that inasmuch as the sensing of torque is primarily accomplished by sensing the change in permeability at the surface of the torqued member, it is at least at the surface of each band that there must be magnetic anisotropy created by residual stress. Hence, the limitation that the applied stress must be at least sufficient to exceed the elastic limit of the member at its surface. It will, of course, be appreciated that the application of an applied stress exceeding the minimum will, depending upon the magnitude of the applied stress, result in residual stress within the body of the member

as well. For use herein, the term "surface" of the member means at the surface and within 0.010 inch thereof.

Any method of applying stress to a member to exceed the elastic limit thereof at the surface of the bands may be employed which produces uneven plastic deformation over the relevant cross-section of the member. Thus, the residual stress inducing method may be mechanical, thermal, or any other which is suitable. It is particularly desirable that the residual stress-inducing applied stress exceed the maximum expected applied stress when the member is torqued in use. This is to insure that torquing during use does not alter the residual stress pattern and, thus, the magnetic anisotropy within the bands. The residual stress induced in the respective bands should be substantially equal and symmetrical in order that axial permeability sensing, when equal axial magnetizing forces are applied to the member, will produce a "no difference" output in the untorqued condition and equal but opposite output as a result of the application of equal clockwise (CW) and counter-clockwise (CCW) torques.

The method chosen to apply stress to a member beyond the elastic limit thereof in order to create residual stress is largely a function of the member's size, shape, material and intended application. The method may induce continuous and substantially equal residual stresses over the entire surface of the band, i.e., around the entire band circumference and along its entire axial length. Alternatively, the method may induce a residual stress pattern within each band which includes both stressed and unstressed areas. Such a pattern, however, is subject to the important limitation that each band must have at least one continuous circumferential region which is free of unstressed areas over at least 50% of its circumferential length, desirably over at least 80% of its circumferential length. In a particularly preferred configuration, each band would have at least one continuous circumferential region which is free of unstressed areas over its entire circumferential length. As a general matter, it is particularly desirable to maximize the amount of shaft surface which is intentionally stressed in order to endow as much of the surface as is possible with relatively large magnitude controlled magnetic anisotropy. This leaves as little of the shaft surface as possible subject only to the random anisotropies created during shaft manufacture, due to internal stresses and resulting from crystal orientation. It should be appreciated that the problems associated with random anisotropy inherent in using the shaft itself as an operative element, i.e., the sensing region, of the magnetic circuit of the torque sensor are overcome, in accordance with the present invention, by replacing and/or overwhelming the random anisotropy with relatively large magnitude intentionally created residual stress induced anisotropy. For obvious reasons, the greater the intentionally induced anisotropy, the less significant is any residual random anisotropy.

As used hereinbefore and hereinafter, the term "circumferential region" means the locus of points defining the intersection of (1) a plane passing perpendicular to the member's axis and (2) the surface of the member, as hereinbefore defined. Where the member is a cylindrical shaft, the circumferential region is a circle defining the intersection of the cylindrical surface with a plane perpendicular to the shaft axis, and such a circle has a circumference or circumferential length. Stated otherwise, if each element of the member's surface comprising the circumferential region were examined, it would be seen that each such element was either stressed or unstressed. In order to form a commercially functional torque sensor having broad applicability, particularly in small diameter shaft applications, which exhibits acceptable and commercially reproducible sensitivity, linearity and output signal strength, it has been found that at least 50% of these elements must have been stressed beyond their elastic limit and, therefore, must remain residually stressed after the applied stress is removed.

The range of methods by which torque carrying members can be endowed with the desired bands containing residual stress instilled helically directed magnetic easy axes, i.e., directions in which magnetization is easiest, is virtually endless. From the point of view of transducer performance the most important consideration is the adequacy of the resulting anisotropy, i.e., the band anisotropy created must be at least of comparable magnitude to the stress anisotropy contributed by the applied torque. From the point of view of compatibility with the device in which the transducer is installed, the compelling consideration is consequential effects on the member's prime function. Other important considerations in selecting a method are practically and economics. Examples of suitable methods for imprinting residual stress induced magnetically directional characteristics on, i.e., at the surface of, a torque carrying member include, but are not limited to, torsional overstrain; knurling; grinding; mechanical scribing; directed or masked shot peening or sand blasting; roll crushing; appropriate chemical means; selective heat treatments, e.g., induction, torch, thermal print head, laser scribing.

Of the foregoing, the creation of areas of residual stress by torsional overstrain has been found to be a simple, economical and effective method for small diameter shafts. It is particularly desirable because it neither distorts nor interrupts the surface of the shaft and is, therefore, compatible with virtually any application. However, the manner of applying torsional overstrain, e.g., by twisting both sides of a centrally restrained region, makes it impractical for and inapplicable to large diameter shafts formed of high elastic limit materials. Knurling is a desirable manner of inducing residual stress in a shaft of virtually any diameter. With knurling, the exact location of the bands, their axial extent, separation and location can be closely controlled. In addition, knurling allows relatively simple control of the helix angles of the easy axes. Very importantly, knurling permits predetermination of the salient features of the knurl itself, such as pitch, depth and cross-sectional shape and, thereby, allows control of the residual stress induced. It should be appreciated that, in accordance with the present invention, enough of the surface of each band must be stressed that there exists within each band at least one continuous circumferential region which is free of unstressed areas over at least 50% of its circumferential length. Not all knurling is this extensive and care must be taken to select a knurl which achieves this objective. Inasmuch as knurling disrupts the surface of the shaft in order to form the knurl thereon, a knurled band is endowed with shape anisotropy as well as residual stress anisotropy. If it is desired, for example, for compatibility of the knurled shaft with an intended application, the gross shape features of the knurl may be ground off the shaft to leave only magnetic anisotropy caused by residual stress. Other forms of cold working, with or without surface deformation, likewise create residual stress and associated magnetic anisotropy. In

addition, more sophisticated methods, such as electron beam and laser scribing as well as selective heat treatment can provide the desired anisotropy with less mutilation of the shaft surface than most mechanical cold working methods. Moreover, these methods offer the opportunity of very close control of the induced residual stresses by adjustment of the power density and intensity of the beam and/or the thermal gradients.

Whatever method may be selected for creating residual stress within the bands, it should be appreciated that the relationship between the percent of stressed areas along the circumferential length of a circumferential region within each band ("% stressed areas") and sensitivity (in millivolts/N-M) is one wherein the sensitivity increases with increasing "% stressed areas". A plot of these parameters yields a curve which has its greatest slope at the lower values of "% stressed areas" and which has a decreasing slope at the higher values of "% stressed areas", up to 100%, at which point the sensitivity is greatest and the slope is close to zero. The precise shape of the curve, its slope for any particular value of "% stressed areas", its initial rate of ascent and the point at which the rate of ascent decreases and the curve levels off are all functions of the material of the bands and the manner in which the stress is applied. A typical curve is shown in FIG. 7. At "A", there is no residual stress along the circumferential length of the circumferential region. At "C", 100% of the circumferential length of the circumferential region is subjected to residual stress. "B" represents the approximate point on the curve at which sensitivity begins to level off, i.e., becomes less responsive to "% stressed areas," a point which is both material and method dependent.

Ideally, torque sensor operation at 100% residual stress, i.e., at "C" on the curve, is best because the rate of change of sensitivity is minimized and the 100% stressed condition is generally easiest to attain with most methods. As a practical matter, it is difficult to control the residual stress inducing method to achieve a value for desired "% stressed area" which is less than 100%. However, practical production problems aside, acceptable torque sensors can be made which operate at sensitivity levels corresponding to less than 100% residual stress along the length of a circumferential region of the bands.

Torque sensor cannot economically and reproducibly be made to operate in the ascending portion AB along the curve in FIG. 7 since, in that portion, the sensitivity is extremely responsive to "% stressed areas". This means that even small changes in "% stressed areas" causes relatively large changes in sensitivity. From a practical, commercial standpoint, mass produced torque sensors must have a known and reproducible sensitivity. It would be unrealistic to have to individually calibrate each one. However, even normal production inconsistencies will cause small "% stressed areas" changes which will result, in the AB region of the curve, in large sensitivity differences among sensors. Therefore, commercially useful torque sensors have to operate along a flatter portion of the curve, where the slope is closer to zero. Operating in the BC portion of the curve appears to be an acceptable compromise. It is preferred, for most materials and residual stress inducing methods, that the point represented by "B" exceed at least 50%, preferably at least 80%, stressed areas along the circumferential length of a circumferential region. This is in recognition of the fact that the minimum acceptable residual stress loading of a circumferential region is both material and process dependent and that it is generally most desirable to be as close to 100% stress loading as is practical.

To demonstrate the applicability of the foregoing in fabricating an operable torque sensor, with reference to FIG. 8, a 0.25 inch OD cylindrical shaft 100 was formed with two shoulders 102 of equal axial length spaced apart by a reduced diameter shaft portion 104 of 0.215 inch OD. The shaft was formed of a nickel maraging steel commercially available as Unimar 300K from Universal-Cyclops Specialty Steel Division, Cyclops Corporation of Pittsburgh, Pennsylvania and was preannealed at 813° C. in hydrogen to relieve internal stresses. Each shoulder 102 was carefully knurled using a pair of identical ¾ inch OD, ¾ inch long knurling rollers having 48 teeth around their circumference. The shoulders were brought into contact with the knurling rollers in a controlled manner to form symmetrical knurls on each shoulder at angles of ±30° to the shaft axis. Careful control of the infeed of the tool relative to the shoulders allowed the axial width and depth of each knurl trough to be controlled. The "% stressed areas" along the circumferential length of a circumferential region of each knurled shoulder was determined by assuming that the knurl trough was the only stressed area on the shoulder and that the shoulder surface between troughs was unstressed by the knurling operation; by measuring the trough width and chordal knurl pitch and converting the chordal pitch to circumferential pitch; and by calculating the trough width to circumferential pitch ratio, which ratio when multiplied by 100 represented the desired "% stressed areas" value. The shaft prepared in this manner was affixed to a lever arm which permitted 10-one pound weights to be suspended from cables at each end of the arm. The lever arm was so dimensioned that addition or removal of a single one pound weight from either side represented a torque change on the shaft of 0.5 N-M. By appropriate shifting of the weights, the torque on the shaft could be altered in both magnitude and direction.

FIG. 9 graphically illustrates the relationship between "% stressed areas" and sensitivity for a shaft prepared as described hereinabove. It can be seen that the curve ascends rapidly up to about 60% stress loading and then appears to level off rather rapidly thereafter. This is because there is believed to be a greater correlation at lower "% stressed area" values between the trough width to circumferential pitch ratio and the actual percentage of stressed areas along the circumferential length of a circumferential region of the shaft. As the width and depth of the knurling trough increases it becomes apparent that the shoulder surface between troughs, at least in the vicinity of the trough edges, becomes slightly deformed and, more than likely, residually stressed. Therefore, the point on the curve at which 100% stress loading in a circumferential region is actually achieved is somewhat less than the calculated 100% value, accounting for the rapid flattening of the curve at the higher "% stressed areas" portions thereof. This suggests that, with many processes, such as knurling, the 100% stress loading point can be achieved with less than 100% topographic disruption. It will be appreciated in this connection, that each method of inducing residual stress in a shaft will produce its own distinctive curve of "% stressed areas" vs. sensitivity, although it is believed that each curve will have the same general characteristics as appear in FIGS. 7 and 9.

In accordance with the foregoing, it can be seen that in the absence of applied torque, the application to the bands of equal axial magnetizing forces causes the bands to respond symmetrically and the sensing means associated with the bands detect no difference in response. When torque is applied, the principal stresses associated with the applied torque combine with the residual stresses in the bands in such a manner that the resultant stresses in the two bands are different from each other. As a result, the magnetic permeabilities are different and the emf induced in the sensing means associated with each band reflect that difference. The magnitude of the difference is proportional to the magnitude of the applied torque. Thus, the instant system senses a differential magnetoelastic response to the principal stresses associated with the applied torque between two circumferential bands. The significance of this is that sensing in this manner amounts to sensing the response averaged over the entire circumference of the band. In this manner, sensitivity to surface inhomogenity, position and rotational velocity are avoided.

This sensing of magnetic permeability changes due to applied torque can be accomplished in many ways, as is disclosed in the prior art. See, for example, the aforementioned article of Harada et al and U.S. Pat. No. 4,506,554. Functionally, the magnetic discriminator is merely a probe for assessing any differential magnetoelastic response to applied torque between the two bands. In general, it functions by imposing equal cyclically time varying magnetizing forces on both bands and sensing any differences in their resulting magnetization. The magnetizing forces may come from electrical currents, permanent magnets, or both. Resulting magnetization may be sensed through its divergence, either by the resulting flux or its time rate of change. The transducer function is completed by the electrical circuitry which delivers an electrical signal that is an analog of the torque.

One method of supplying the magnetization forces and for measuring the resulting difference signal from the sensing coil is shown in FIGS. 2 and 3. Referring to FIG. 2, it can be seen that the bands 6,8 are surrounded by bobbins 16,18 which are concentric with shaft 2. Mounted on bobbins 16,18 are a pair of coils 20,22 and 24,26 of which 22 and 26 are excitation or magnetizing coils connected in series and driven by alternating current and 20 and 24 are oppositely connected sensing coils for sensing the difference between the fluxes of the two bands. A ferrite material core 28 is optionally provided as a generally E-shaped solid of revolution. Circumferential gaps 30 between the shaft and the E-shape core are desirably maintained as small and uniform as is practical to maintain the shaft centered within the core. FIG. 3 shows that excitation or drive coils 22,26 are supplied in series from AC source 32 and the emf induced in the oppositely connected sensing coils 20,24 is phase sensitively rectified in the rectifier 34 and is displayed on voltage display instrument 36. Black dots 38 indicate the polarity of the coils.

Inasmuch as the stresses in the bands are symmetrical and equal when no torque is applied to shaft 2, under these conditions the output signal from the circuitry shown in FIG. 3 will be zero, regardless of the applied a.c. driving input. This is because the bands have equal magnetic permeability. Thus the voltages induced in the sensing coils are equal in magnitude and opposite in polarity and cancel each other. However, when a torque is applied to shaft 2, the respective bands will be subjected to tensile and compressive stresses, with a resulting increase of permeability and of the flux passing through one of the bands, and a resulting decrease of permeability and of the flux passing through the other of the bands. Thus, the voltage induced in one of the sensing coils will exceed the voltage induced in the other sensing coil and an output signal representing the difference between the induced voltages and proportional to the applied torque will be obtained. The signal is converted to a direct current voltage in the rectifier 34 and the polarity of the rectifier output will depend upon the direction, i.e., CW or CCW, of the applied torque. Generally, it has been found that in order to obtain linear, strong output signals, the a.c. driving current should advantageously be maintained in the range 10 to 400 milliamperes at excitation frequencies of 1 to 100 kHz.

FIG. 4 illustrates another type of magnetic discriminator for sensing the permeability change of the bands upon application of a torque to the shaft. Magnetic heads 42,44 comprising a ferromagnetic core and a coil wound thereupon are provided in axial locations along shaft 40 which coincide with bands 46,48 and are magnetically coupled to the bands. The magnetic heads 42,44 are excited by high frequency power source 50 through diodes 52,54. With no torque applied to shaft 40, the magnetic permeability of the bands are equal. Therefore, the inductance levels of both magnetic heads are equal and opposite in polarity, and the net direct current output, V_{out}, is zero. When torque is applied to shaft 40, as shown by arrows 60, the magnetic permeability of one band increases while the permeability of the other decreases. Correspondingly, the inductance of one magnetic head increases while the inductance of the other decreases, with a resultant difference in excitation current between the heads. This difference in excitation current, passed via output resistors 56 and smoothing capacitor 58, produces a direct current output signal which has polarity and magnitude indicative of the magnitude and direction of the applied torque.

In accordance with one unique aspect of the present invention, as hereinbefore described, a shaft of suitable material is endowed in each of two proximate bands with symmetrical, left and right handed helical magnetic easy axes. At least in the region of the bands, and more commonly over its entire length the shaft is formed, at least at its surface, of a material which is ferromagnetic and magnetostrictive. The material must be ferromagnetic to assure the existence of magnetic domains and must be magnetostrictive in order that the orientation of the magnetization may be altered by the stresses associated with an applied torque. Many materials are both ferromagnetic and magnetostrictive. However, only those are desirable which also exhibit other desirable magnetic properties such as high permeability, low coercive force and low inherent magnetic anisotropy. In addition, desirable materials have high resistivity in order to minimize the presence of induced eddy currents as a result of the application of high frequency magnetic fields. Most importantly, favored materials must retain these favorable magnetic properties following the cold working and heat treating necessary to form them into suitable shafts having appropriately high strength and hardness for their intended use.

It is true that many high strength steel alloys are ferromagnetic and maguetostrictive. However, to varying degrees, the vast majority of these alloys experience a degradation in their magnetic properties as a result of

the heat treating necessary to achieve suitable hardness and strength for the desired application. The most significant degradation is noted in those alloys hardened by carbon or carbides for which the conventional inverse relationship between mechanical hardness and magnetic softness appears to have a sound basis. However, the performance of even low carbon alloys such as AISI 1018 is found to significantly degrade with heat treating. The same is true for martensitic stainless steels, e.g., AISI 410, and highly alloyed steels, e.g., a 49Fe-49Co-2V alloy. It has been determined, in accordance with another unique aspect of the present invention, that the nickel maraging steels possess the unusual combination of superior mechanical properties and outstanding and thermally stable magnetic properties which give them a special suitability and make them particularly advantageous for use in all magnetoelastic torque transducers in which a magnetic field is applied to ferromagnetic, magnetostrictive means and the change in permeability caused by torque applied thereto is sensed to obtain an indication of the magnitude of the applied torque. This is the case whether the ferromagnetic, magnetostrictive means is affixed to, associated with or forms a part of the surface of the torqued member and whether or not the ferromagnetic, magnetostrictive means is endowed with bands of intentionally instilled magnetic anisotropy and irrespective of the number of bands which may be used.

The nickel maraging steels are, typically, extra-low-carbon, high nickel, iron-base alloys demonstrating an extraordinary combination of structural strength and fracture toughness in a material which is readily weldable and easy to heat-treat. They belong to a loosely knit family of iron-base alloys that attain their extraordinary strength characteristics upon annealing, by transforming to an iron-nickel martensitic microstructure, and following cooling, upon aging in the annealed or martensitic condition. Thus, the alloys are termed "maraging" because of the two major reactions involved in their strengthening—martensitizing and aging. However, these steels are unique due to their high nickel and extremely low carbon content, which permits formation of an outstandingly tough martensite that can be strengthened rapidly to extraordinarily high levels. Yield strengths up to and well beyond 300 ksi are available in these steels in the aged condition.

Typical nickel maraging steels are alloys compriaing 12–25% Ni, 7–13% Co, 2.75–5.2% Mo, 0.15–2.0% Ti, 0.05–0.3% Al, up to 0.03% C, balance Fe and incidential amounts of other elements, such as Mn, Si, S, P, Cb. The most popular and practically significant maraging steels, at least at present, are the 18% Ni steels which can be aged to develop yield strengths of about 200 ksi, 250 ksi and 300 ksi. These particular alloys, referred to as 18Ni200, 18Ni250 and 18Ni300 grade maraging steels have typical compositions in the ranges 17–19% Ni, 7–9.5% Co, 3.0–5.2% Mo, 0.1–0.8% Ti, 0.05–0.15% Al, up to 0.03% C, balance Fe and incidential amounts of other elements. Typically, the 18% nickel maraging steels are heat treated by annealing at temperatures of 1500° F. and above for a sufficient time, e.g., one hour per inch of thickness, to dissolve precipitates, relieve internal stresses and assure complete transformation to austenite. Following air cooling, the 18% Ni steels are conventionally aged at 750°–1100° F., desirably 900°–950° F., for 3 to 10 hours, depending upon thickness, usually 3–6 hours. However, it has been found that satisfactory strength characteristics and superior magnetic characteristics can be attained in alloys aged for as little as 10 minutes.

Other well known nickel maraging steels are cobalt-free 18% Ni maraging steels as well as cobalt-containing 25% Ni, 20% Ni and 12% Ni maraging steels. The 18% Ni-cobalt containing maraging steels are commercially available from a number of sources. Thus, such steels are obtainable under the trademarks VascoMax C-200, VascoMax C-250, VascoMax C-300 and VascoMax C-350 from Teledyne Vasco of Latrobe, Pennsylvania; under the trademarks Marvac 250 and Marvac 300 from Latrobe Steel Company of Latrobe, Pennsylvania; under the trademark Unimar 300K from Universal-Cyclops Specialty Steel Division, Cyclops Corporation of Pittsburgh, Pennsylvania; and, under the trademark Almar 18-300 from Superior Tube of Norristown, Pennsylvania. The 18% Ni-cobalt free maraging steels are commercially available under the trademarks VascoMax T-200, VascoMax T-250 and VascoMax T-300 from Teledyne Vasco of Latrobe, Pennsylvania. Other high nickel steels which form an iron-nickel martensite phase exhibit mechanical and magnetic properties which are similar to those of the more conventional maraging steels and which are also substantially stable to temperature variations. Most notable among these is a nominally 9% Ni-4% Co alloy available from Teledyne Vasco having a typical composition, in percent by weight, of 9.84 Ni, 3.62 Co, 0.15 C, balance Fe. In addition, maraging steels of various other high nickel-cobalt compositions, e.g., 15% Ni-15% Co, are continously being tested in efforts to optimize one or another or some combination of properties. Therefore, as used herein, the term "Ni maraging steel" refers to alloys of iron and nickel which contain from 9–25% nickel and which derive their strength characteristics from iron-nickel martensite formation, as hereinbefore described.

In addition to their outstanding physical and strength characteristics, the nickel maraging steels have excellent magnetic properties which make them outstanding for use as the magnetic material in non-contact torque transducers. Thus, they have high and substantially isotropic magnetostriction, in the range of 25 ppm±15 ppm, and do not exhibit a Villari reversal; high electrical resistivity; low inherent magnetic anisotropies due to crystalline structure; high magnetic permeability; low coercive force, in the range 5–25 oersted; and, stability of magnetic properties with alloy chemistry. However, most important is that their magnetic properties are only modestly, yet favorably, affected by strengthening treatments—indeed, their magnetic properties improve with cold work and aging heat treatment. This characteristic distinguishes the nickel maraging steels from all other high strength alloys. Heretofore, it had been the conventional wisdom that the heat treatments needed to improve the mechanical and strength properties of steels were detrimental to their magnetic properties. For example, quench hardened steel alloys typically exhibit very low magnetic permeabilities and high coercive forces, a combination of unfortunate magnetic properties which materially decrease the sensitivity of such alloys to small magnetic fields and diminish or negate their usefulness in torque transducers such as are contemplated herein. This is demonstrably not the case with the nickel maraging steels. In accordance with the present invention it has been determined that nickel maraging steels get magnetically softer following cold work and the aging heat treatments to which they are conventionally subjected

in order to develop their extraordinary high strength characteristics. For example, the coercive force of an 18% Ni maraging steel in fact decreases when aged at 900° F. for up to 10 hours. As a result the maraging steels can be advantageously used in their aged condition, i.e., in a condition where they exhibit maximum strength characteristics and substantially the same or improved magnetic characteristics.

Thus, the use of maraging steels as the magnetic material in a magnetoelastic torque sensor, particularly as the shaft material in a device whose torque is to be sensed, obviates virtually all of the objections heretofore made to using the device shaft as the magnetic member. The mechanical and strength properties of maraging steels satisfy the mechanical properties requirements for most all shaft applications while, at the same time, providing outstanding magnetic properties for its role in the torque sensor. Aging of the maraging steels provides the high strength and high hardness needed for the mechanical application without loss of magnetic permeability or increase in coercive force. Moreover, the conventional manner of heat treating maraging steel, including the initial solution anneal at temperatures in excess of 1500° F., relieves internal stresses due to mechanical working and most stresses due to inhomogeneities and crystal orientation, thus minimizing the amount of random magnetic anisotropy in a maraging steel shaft. When such heat treatment is combined with the creation, according to the present invention, of a pair of adjacent bands endowed with intentionally instilled magnetic stress anisotropy of a relatively large magnitude, e.g., by stressing the shaft beyond its elastic limits with applied stresses of a magnitude greater than the largest torque stresses anticipated during normal usage of the shaft, the contribution to total magnetic anisotropy of any random anisotropy in the shaft is indeed negligible.

It will be appreciated that the advantage of the nickel maraging steels in magnetoelastic torque transducers can be realized by forming the shaft of the desired nickel maraging steel, by forming a region of the shaft of the desired nickel maraging steel and locating the annular bands within this region, or by surfacing with a nickel maraging steel a shaft formed of an alloy having mechanical properties suitable for the intended function of the shaft, i.e., applying over at least one complete circumferential region of suitable axial extent of the shaft a surfacing alloy of the desired nickel maraging steel and locating the annular bands within this region. Inasmuch as magnetic permeability sensing in accordance with the present invention is fundamentally a surface phenomena, the surfacing process need apply a circumferential layer of thickness not exceeding about 0.015 inches. The surfacing process selected may advantageously be selected from among the many known additive processes, e.g., electroplating, metal spraying, sputtering, vacuum deposition, ion implanatation, and the like.

In order to demonstrate the outstanding qualities of the maraging steels as the magnetic material in torque transducers of the present invention and to compare the performance of maraging steels with other high strength steels, a torque transducer was assembled using a 12.7 mm diameter cylindrical shaft having formed thereon a pair of axially spaced-apart bands endowed with helically symmetrical LH and RH magnetic easy axes. The bands each had an axial length of 12.7 mm and were separated by a 12.7 mm shaft segment. They were formed by knurling using a ¾-inch OD knurling tool having 48 teeth around the circumference, each tooth oriented at 30° to the shaft axis. The characteristics of this arrangement were sensed by positioning bobbins concentric with the shaft and axially aligned with the bands, each bobbin having a magnetizing and sensing coil mounted thereon. The magnetizing coils were connected in series and driven by an alternating current source having a 10 KHz frequency output and a 200 mA peak driving current. The emf induced in each of the sensing coils was separately rectified with the rectified outputs oppositely connected to produce a difference signal which was displayed on a voltage display instrument. Four shafts were employed, identical in all respects except they were each formed of different materials. The composition of each shaft is set forth in percent by weight hereinbelow:

T-250: 18.5 Ni; 3.0 Mo; 1.4 Ti; 0.10 Al; less than 0.03 C; no cobalt; balance Fe

SAE 9310: 0.08–0.13 C; 0.45–0.65 Mn; 3–3.5 Ni; 1–1.4 Cr; 0.08–0.15 Mo; balance Fe

416 SS: 11.5–13.5 Cr; 0.5 max Ni; 0.15 max C; 1.0 max Mn; 1.0 max Si; balance Fe

AISI 1018: 0.15–0.20 C; 0.6–0.9 Mn; 0.04 max P; 0.05 max S; balance Fe

In a first series of runs, the T-250 nickel maraging steel shaft was used in the solution annealed, unaged condition as received from Teledyne Vasco. Likewise, the other shafts were also used in their aspurchased condition without further heat treatment. A known torque loading was applied to each shaft under test and the output voltage signal was recorded. The applied torque was increased from zero up to 100 newton-meters (N-M). FIG. 5 is a graph of applied torque versus output d.c. voltage for each shaft. It is apparent that the sensitivity of the T-250 shaft in terms of magnitude of output signal for a given torque loading was significantly greater than for the other shaft materials tested. In addition, the linearity of the output signal for the T-250 shaft was extremely good over the entire torque range. The other shaft materials appeared to be about equally insensitive, compared to the T-250 shaft, to applied torque. None produced as linear a signal as the T-250 shaft, although each produced a reasonably linear signal over most of the torque range.

For the second series of runs, the T-250 nickel maraging steel shaft was aged at about 900° F. for 30 minutes to improve the strength and hardness of the shaft. For consistency of testing, the other shafts were heat treated in the same manner, after which each shaft was subjected to an applied torque from zero to 100 N-M and the output d.c. voltage recorded. FIG. 6 is a graph of applied torque versus output d.c. voltage for each shaft after heat treatment. It can be seen that once again the sensitivity of the T-250 shaft far exceeded the sensitivity of the other shafts and once again the T-250 output signal was linear over the entire torque range. By comparison with FIG. 5 for the T-250 shaft in the unaged condition it is apparent that aging measurably improved the sensitivity of the shaft, indicating an enhancement of the magnetic properties of the maraging steel with aging. By contrast, the sensitivity of the SAE 9310 shaft did not appear to improve with this heat treatment. Moreover, the linearity of the output signal clearly degraded, particularly at higher applied torques. The sensitivity of the AISI 1018 shaft significantly improved at low applied torques but the improvement began to abate at about 40 N-M and degraded thereafter. The

linearity of the output signal for the aged AISI 1018 shaft was very poor. For the 416 SS shaft, the sensitivity at low applied torques improved with heat treatment but significantly worsened at higher applied torques. The linearity of the 416 SS output signal became worse with heat treatment. It is noteworthy that notwithstanding the mixed response of the output signal to applied torque, heat treatment adversely affected the mechanical and strength properties of the SAE 9310, 416SS and AISI 1018 shafts. For example, following heat treatment, an applied torque of only about 50 N-M exceeded the elastic limit of the AISI 1018 shaft and the shaft permanently twisted.

FIGS. 5 and 6 graphically illustrate the signal response to applied torque using a relatively low, 10 kHz, a.c. excitation frequency. It has been found that the output signal is directly proportional to and increases approximately linearly with a.c. frequency. Tests show that at 20 kHz, for example, a doubling of the output d.c. voltage signal is obtained. Depending upon the circuitry employed, a.c. frequencies in the range 1–100 kHz can advantageously be used to drive torque transducers of the present invention. Preferably, frequencies of 10–30 kHz, just above the human audible range, are used in order to avoid whistling. Most desirably, the frequency is adjusted to about 20 kHz. Like its response to frequency, the output d.c. signal also appears to be directly proportional to, more specifically to vary sigmoidally with, the drive current which, depending upon the frequency, can usefully be in the range 10–400 mA (peak). Generally, sufficient current is used to obtain a good signal at the chosen frequency and, desirably, to adjust the signal hysteresis to zero over the entire applied torque range.

It is interesting to note that the sensitivity of a nickel maraging steel shaft is markedly better than the sensitivities reported by workers employing nonmagnetic shafts and adhesively affixing amorphous ribbons thereto. From FIG. 6, it can be seen that according to the present invention an aged T-250 nickel maraging steel shaft transducer, having a shaft diameter of 12.7 mm, produces an output d.c. signal of 0.9 volts at an applied torque of 60 N-M using an a.c. frequency of 10 kHz and an exciting current of 200 mA and employing exciting coils having 100 turns each and sensing coils having 500 turns each, a sensitivity of 0.015 V/N-M. By comparison, Sasada et al, in the paper "Noncontact Torque Sensor", presented at the 11th Annual IEEE Industrial Electronics Society Conference (Nov. 18–22, 1985) reports, for an amorphous ribbon torque sensor, an output d.c. signal of 35 mV at an applied torque of 10 N-M using an a.c. frequency of 20 kHz, an exciting current of 120 mA, exciting coils having 220 turns each and sensing coils having 80 turns each and a shaft diameter of 12 mm. Inasmuch as sensitivity is directly proportional to a.c. frequency, exciting current and number of turns on the exciting and sensing coils and inversely proportional to the cube of the shaft diameter, the Sasada et al sensitivity corrected to an equivalent basis as that shown in FIG. 6 hereof is 0.007 V/N-M. In other words, the torque transducer of the present invention is more than twice as sensitive as the amorphous ribbon torque sensor of Sasada et al.

INDUSTRIAL APPLICABILITY

The unique and improved magnetoelastic torque transducers of the present invention are broadly useful for the sensing and measurement of torque in members of all types and sizes, whatever may be the device or field of application in which the member operates. It is universally accepted that torque is an absolutely fundamental parameter in the control of systems having rotating members. Sensing the instantaneous torque experienced by a rotating member and generating an electrical current in response thereto which bears a known relationship to the torque allows the early diagnosis of incipient problems or the control, via microprocessor or otherwise, of the engine, machine, motor, etc. which drives the rotary member.

Applications for the torque transducers of the present invention can be found in virtually every device having a rotating member. There already is a demand for sensitive, responsive, and inexpensive magnetic torque sensors for monitoring torque in engines and power drives to improve overall performance and fuel economy, control exhaust emissions and modulate transmission ratios; in marine propulsion systems to detect and correct reduced output from the propulsion machinery and the effects of hull fouling and propeller damage; in helicopter turbines to avoid overloading and to detect power loss caused, for example, by sand or salt spray. There is also a demand for torque transducers such as are provided in accordance with the present invention for controlling heavy industrial machinery of all types, e.g., pulp grinders for maintaining fiber quality, papermaking machines, and the like, as well as for use in consumer home and commercial appliances, e.g., food mixers and processors. In addition, the need for small, inexpensive, sensitive, reliable torque sensors has been noted in such diverse applications as machine and hand tools, robotics, information devices, industrial measuring instruments, weighing systems of various kinds, electronic power assisted power steering, and vehicular traction balancing.

One application for the magnetoelastic torque transducers of the present invention which is particularly promising in view of the potential contribution of these transducers to energy conservation, environmental cleanliness and safety and because it directly affects so many people and businesses is its use on internal combustion engines and associated engine power drives. The torque sensor of the present invention is capable of recovering the torque signature of an engine over a wide enough bandwidth to discern salient details of important torque contributing events at all points between idle and the top operating speed of the engine. Torque sensing in an accurate and cost effective manner enables early diagnosis of incipient problems due to the functional condition of the engine, helps to avoid unanticipated failures that might limit the servicability of the vehicle at critical times and improves and/or controls the performance and economy of the engine and its power drive.

Primary power for the propulsion and other essential functions of modern vehicles is obtained from the rotating output shaft of an internal combustion engine. Regardless of the type of engine the power actually delivered by this shaft to the vehicle is the numerical product of only two parameters: rotational speed and transmitted torque. Of the two, torque is the intensive parameter since rotational speed is itself consequential to the internally developed torque of the engine. It is the magnitude of available torque that sets the limits on vehicle acceleration, its speed on grade and other mobility and performance factors. The successful use and enjoyment of the vehicle depends, ultimately, on the ability of its

engine to deliver the functionally required torque throughout its operational range of speeds.

Except for the situation where a turbine engine is driving a constant load, the torque transmitted through an engine output shaft fluctuates rapidly. These fluctuations reflect both the cyclic variations in the torque developed by the engine and transient variations in the torque imposed by vehicle loads. In piston engines, torque is developed by each cylinder only during its power stroke. Multicylinder engines attain some continuity of developed torque by the overlap of phased power strokes from each cylinder. While cyclic variations in output torque are also reduced thereby, and further reduced by the combined inertia of the engine's internal moving parts, the strongly impulsive nature of each cylinder's developed torque is still transmitted through the output shaft. Cyclically stimulated torsional vibrations together with the changing accelerations of linked reciprocating parts contribute additional time varying torque components. The magnitude and even the directional sense of this torque is further influenced by variations in operational conditions of the vehicle, e.g., throttle settings, gear positions, load pick-up, road surface inclination and roughness features.

Although the torque on the engine output shaft represents the superposition of contributions from this multiplicity of sources, many are strongly interdependent and their combination forms an effective signature characterizing the engine's performance. Salient features of this signature would clearly correlate with specific engine events, e.g., cylinder firings. The absence of a normal feature, its alteration or the development of new features would be a reflection of a dysfunction. The nature and extent of the abnormality would be symptomatic of specific engine or drive line difficulties. While many engine problems are also detectable by their symptomatic effects on overall performance and/or more objectively measurable quantities (e.g., manifold pressure, compression, noise signature, exhaust gas analysis), none are as sensitively quantified as torque to the individual events which together characterize proper engine function. Since torque is the effective product of the engine, no measurements of indirectly related parameters can so clearly identify the source of inadequate production as can the measurement of torque itself. Conventional methods of recovering torque data, whether by dynamometer or from measurements of unloaded engine acceleration and deceleration by procedures involving stepped changes in fuel flow and/or ignition interruption, determine only average values and lack the detail needed for clear diagnosis and control. Recovery and analysis of the information contained in the torque signature of the engine output shaft enables diagnosis of incipient problems, helps to avoid unanticipated failures that might limit the serviceability of the vehicle at critical times and improves and/or controls the performance and economy of the engine and its power drive. The key to the problem is the recovery of enough torque information for a meaningful analysis.

In a 12 cylinder, 4 stroke engine operating at 4000 rpm there are 400 power strokes and (at least) 1600 valving events (openings or closings) every second. Turbine engines run with far smoother power input but at speeds up to 500 revolutions per second. To be capable of discriminating important details of these salient events, the torque sensing system must have a reasonably flat frequency response up to at least several times the maximum event rate, i.e., in the vicinity of 5 kHz. The frequency response must also extend downward to zero Hz to faithfully capture the steady state torque components imposed by the vehicle loads.

Although that full bandwidth is obviously desirable for maximum utility as a diagnostic tool, the information contained in the low frequency spectrum, up to 10 Hz, accurately describes the engine's overall response to control (input) and load (output) changes. Not only can variations in performance be objectively evaluated from this information but it also has potentially prime utility in another area, control of the engine and associated power drive.

A torque sensor having 5 kHz bandwidth capability cannot be positioned arbitrarily. While torque is applied to the engine shaft by contact forces at discrete locations, it is transmitted axially by continuous stress distributions. Transient torque events are not transmitted instantaneously nor do they remain unaltered along the shaft. The finite elasticity and inertia of real shaft materials combine to limit the transmittable rate of change of torque. Steep transients trigger oscillatory exchanges of elastic and kinetic energy (stress waves) which travel with material and mode dependent characteristic velocities along the shaft. The fidelity of the transmitted torque is further reduced with distance from its source by the accumulated dissipative effects of internal and external friction. The sensor must therefore be located close enough to the source(s) to avoid losing the desired torque information either by attenuation or in background "noise" composed of complex combinations of interfering and reflecting stress waves.

Important sensor requirements are that it be small, at least in the dimension parallel to the shaft axis, that it be rugged and that it be free from deteriorating effects of use or time such as wear, corrosion or fatigue. The sensor should be amenable to performance verification and calibration, especially in the event of repair or replacement of parts of the torque sensing system, including the engine shaft. It should have neglible impact on engine and drive line manufacturability, operation and maintenance and, under no circumstances should the failure of the torque sensor have any contingent consequences which interfere with the otherwise normal operation of the vehicle.

Another promising and very different application for the magnetoelastic torque transducers of the present invention is their use in hand tools, particularly tools such as screwdrivers, wrenches, and the like, e.g., for applying predetermined and pre-set torque to fasteners. Torque tools have become widely used and very important as industrial production and quality control tools for effecting proper tension on bolts, screws, and the like, to insure optimum tightness in the assembly of products of which these fasteners are a part. It is well known that fasteners have mechanical stress limits which, if exceeded, cause them to weaken or break. Therefore, torque tools for applying or checking the torque levels in fasteners have become indispensable in maintaining quality control by eliminating the guesswork which would otherwise be associated with conventional wrench or screwdriver tightening of assembled products.

Most typically, hand operated torque tools used for assembly or disassembly are of the type which can be pre-set to the desired torque level. When the desired torque is reached, the tool either releases, thereby preventing further torque from being applied, or signals the

user, as by a visual indication or audible signal, that the desired torque has been reached. Torque tools which automatically release when the desired torque has been reached have the advantage that overtorquing is not possible, despite inattention of the user. However, the repetitive releasing of the tool on each and every fastener each time the desired torque is reached is disconcerting and annoying, particularly to the skilled worker, wastes time and, therefore, contributes to inefficiency. Tools which provide a visual indication that the desired torque has been reached, such as by providing an indicator dial or lighting a bulb, avoid many of the shortcomings of automatic release tools. However, in many situations the location of the fastener is such that the user is physically unable to simultaneously apply the torque and view the visual indicator. Therefore, the use of an audible signal to indicate when the desired torque has been reached is much to be preferred.

In accordance with the present invention there is provided a hand tool for applying torque to a fastener which, employing the magnetoelastic torque transducers of the present invention, constantly senses the torque being applied and provides an audible signal when a pre-set torque level has been attained. The torque tool of the present invention is well balanced, comfortable to use, rugged and able to sustain abuse, convenient to adjust and maintain, accurate and reliable, and inexpensive to fabricate.

Referring to FIGS. 10, 11 and 12, one embodiment of the torque tool of the present invention is shown generally at 200. Tool 200 includes a gripping handle 202 non-rotatably coupled to shaft 204 such that shaft 204 rotates with handle 202 as a turning moment is applied thereto. Likewise, the free end of shaft 204 is adapted to non-rotatably receive a fastener engaging means, such as a screwdriver bit 206, such that the turning movement applied to handle 202 is transmitted via shaft 204 to bit 206. Although the torque tool is illustrated herein as a torque screwdriver, it should be understood that the present invention is equally applicable to any similarly operated torque tool. Therefore, the fastener engaging means is not intended to be limited to the conventional flat blade screwdriver bit illustrated, but also embraces other suitable bits such as, for example, Phillips head, Allen head, socket head, and the like.

Handle 202 comprises a hollow, generally cylindrical housing which is advantageously made of electrically non-conducting material such as plastic, wood, and the like, having flats formed on the outer surface thereof to facilitate gripping. Closing the topmost or open end 212 of handle 202 is a removable cap 208 having an integral externally threaded sleeve 210 for screw threadably engaging and being held securely by corresponding threads formed within the open end 212 of handle 202. Handle 202 advantageously tapers at its innermost end 214 and includes bore 216 formed in end 214 for communicating with the hollow interior of the handle. Bore 216 is preferably non-round, e.g., square, rectangular, hexagonal, etc. in cross-section, desirably containing a plurality of flat surfaces, for engaging corresponding flat surfaces of shaft adapter 218 which may be press fit within bore 216. One end portion 222 of shaft 204 is removably received within bore 220 of adapter 218 and interlocked therein against rotation relative to the adapter. This may be accomplished in many well known ways, such as by providing flats on shaft end portion 222 which engage corresponding flats formed in bore 220 while the diameters of end portion 222 and bore 220 are sufficiently close that the shaft fits tightly within the bore. The opposite or free end of shaft 204 has a bit receiving socket 224 rigidly affixed thereto in which screwdriver bit 206 is received. Socket 224 is of a conventional type and is adapted to securely hold the shank portion 226 of bit 206 therewithin in such tight engagement that the bit will not rotate relative to the socket. One means for accomplishing this is to utilize a conventional hexagonal bore, ball and spring socket in which a metal ball 228 partially protrudes through the socket wall into the socket bore and is retained in place by a spring clip 230 extending circumferentially around the socket wall for biasing the ball into the socket. The clip forces the ball inwardly into tight engagement with the sidewalls of hexagonal bit shank portion 226 to securely hold the bit within the socket while the flats of the hexagonal socket bore engage the flats of the hexagonal shank portion 226 to prevent relative rotation.

A magnetoelastic torque transducer in accordance with the present invention is formed on shaft 204 in a region intermediate its ends and, desirably, closely adjacent end portion 222. Shaft 204 is formed of ferromagnetic and magnetostrictive material or at least has a ferromagnetic and magnetostrictive region in which a pair of axially spaced apart circumferential bands 232, 234 are formed. The bands are endowed, as hereinbefore described, with respectively symmetrical, helically directed magnetic stress anisotropy. In an exemplary form of the invention, the shaft is formed of Unimar 300, an 18% nickel maraging steel, which has been machined from its 0.250 inch original diameter to provide two axially spaced apart regions 0.30 inch long and 0.200 inch in diameter, separated by an intermediate shaft portion 236 having an axial length of 0.15 inch and provided with opposite flats for clamping. Following machining the shaft is annealed at 815° C. to remove internal stresses formed during machining and is then air cooled. The shaft is clamped in a vise along intermediate portion 236 and end 222 of the shaft is twisted in a clockwise direction to provide a torsional overstrain in one of the reduced diameter regions, corresponding to band 232. The shaft is then repositioned in the vise so that the opposite, free end is located where end 222 was originally and the free end is twisted in a counterclockwise direction to provide an oppositely directed torsional overstrain in the other reduced diameter region, corresponding to band 234. Following twisting, the shaft is aged 10 minutes at 480° C.

A magnetic discriminator for sensing the permeability change of bands 232,234 upon application of a torque to shaft 204 via handle 202 and exemplary indicator circuitry are illustrated in FIG. 12 (excluding conventional voltage regulator circuitry to assure a constant V_{cc}). The discriminator includes a pair of coils 238,240 formed on a non-conducting, e.g., cardboard sleeve 242, and positioned in axial locations corresponding to bands 232 234. A coil cover 272 (see FIG. 11) is desirably provided for protecting the coils when the tool is in use. The remainder of the discriminator circuitry as well as the audible indicator and the indicator circuitry are housed within the hollow bore of handle 202. A conducting metal sleeve 244, closed at one end for housing battery 246 and providing spring contact 248 as a first battery terminal contact, is positioned adjacent end 212 of handle 202. Axially spaced from battery 246 within handle 202 by non-conducting spring 250 is the encapsulated electronics package 252 of the transducer comprising the multivibrator and indicator circuitry illus-

trated in FIG. 12. A second battery contact 254 and a circumferential sleeve contact 255 are formed on the rearmost portion of the encapsulated package adjacent and facing battery 246. A battery connect/disconnect switch 256 is located in a recess of handle cap 208 and is mechanically cammed to detent mechanism 258 to slide battery 246 and sleeve 244 forward, in the switch ON position, into electrical contact with contacts 254 and 255. In the switch OFF position, detent mechanism 256 allows spring 250 to slide battery 246 and sleeve 244 rearwardly out of electrical contact with contacts 254 and 255. Cables 260, 262, 264 extend forwardly from electronics package 252 via wire harness keyway 268 in shaft adapter 218 to electrically connect coils 238,240 to the corresponding circuitry within electronics package 252. An applied torque calibration knob 270 for setting the torque at which audible indicator 266 will signal, is positioned at a convenient location along the outer surface of handle 202. Knob 270 is coupled to a potentiometer P_1 in the multivibrator and indicator circuitry.

In operation of the torque tool of the present invention an appropriate bit for engaging the fastener to be torqued is inserted in socket 224, switch 256 is operated to the ON position and knob 270 is turned to the appropriate torque setting for the particular fastener. Adjustment of knob 270 alters the resistance of potentiometer P_1 which alters the circuit characteristics and, correspondingly, the applied torque at which indicator 266 produces an audible signal. Bit 206 is placed in operative engagement with the fastener to be tightened (or loosened) and handle 202 is rotated in the appropriate direction, thus rotating the fastener. As the fastener tightens, the resistance to turning increases requiring application of additional torque to overcome the resistance. In the manner previously described herein, the torque applied to handle 202 and transmitted to bit 206 is also present in shaft 204. When torque is applied to shaft 204 the magnetic permeability of one band 232,234 increases while the permeability of the other decreases. In the multivibrator circuit shown, only one of the transistors Q_1, Q_2 conducts at a time, thus allowing a square wave voltage to create a cyclically time varying magnetic field for application to the bands 232,234 with the result that the inductance of one coil 238,240 increases while the inductance of the other decreases. This difference in inductance produces different voltage signals V_1, V_2 which enter the operational amplifier OA 1, serving as a comparator, for comparing V_2 and V_1. If V_2 exceeds V_1, then V_{out} will be positive and indicator 266 will produce an audible signal. If V_1 exceeds V_2, then V_{out} will be zero and no audible signal will be produced.

Variable potentiometer P_1 effectively acts to increase V_1 while the applied torque increases V_2. Therefore, if it is desired to apply a large torque to a fastener, knob 270 is operated to increase the resistance in the R_1 circuit, which has the effect of increasing V_1. With V_1 large, V_2, the voltage indication of applied torque, must even be larger in order for V_2 to exceed V_1 to produce an audible signal. Since it requires a large applied torque for V_2 to be large, it follows that with knob 270 adjusted to increase the resistance contribution of P_1 to the R_1 circuit, the audible signal will not be produced until the applied torque is large. Conversely, with knob 270 adjusted to minimize the resistance contribution of P_1 to the R_1 circuit, a smaller applied torque will produce an audible signal.

The torque tool of the present invention has been described herein as a self-contained, stand alone tool which includes, in a single hand held unit, the torque transducer, all necessary electronics, power source and torque indicator. However, in many industrial applications it may be more desirable to distribute the operational and functional features between a hand held portion and a separate stationary portion. Thus, functionally, the very same torque tool may be embodied in a wireless system combining a hand tool containing the torque transducer, a power source and such electronics as is required to radiate a signal, modulated by the torque, e.g., via infra red or radio frequency, to a nearby receiver in which is housed such additional electronics as are required to provide the torque indication. In still another form, the same functional torque tool may be embodied in a wired system combining a hand tool containing the torque transducer with minimal local electronics which is connected via wire to a control unit containing the power source and such other electronics as are required to provide the torque indication.

The context is clear, whether for engines, power drives, machine or hand tools, or other uses, a suitable torque sensor should be an unobtrusive device that is difficult to abuse and is capable of reliably recovering much of the torque information available on the torqued shaft. None of the heretofore contemplated state of the art torque transducers can meet these requirements. However, the magnetoelastic torque sensors of the present invention appear eminently suitable in all respects and will, for the first time, make inexpensive, reliable and sensitive torque sensors available for commerical implementation.

I claim:

1. A hand tool for applying torque to a fastener including fastener-engaging means, handle means to which torque is hand-applied and torque carrying means operatively coupled with said handle means and said fastener-engaging means for transmitting the hand-applied torque to the fastener, said torque carrying means including a magnetoelastic torque transducer, said torque carrying means comprising a member having a ferromagnetic and magnetostrictive region formed of nickel maraging steel, said transducer comprising:
   - a pair of axially spaced-apart annular bands defined within said region, said bands having respectively symmetrical right and left hand helically directed residual stress created magnetic anisotropy, each said band having at least one circumferential region which is free of residually unstressed areas over at least 50% of its circumferential length;
   - means for applying a cyclically time varying magnetic field to said bands;
   - means for sensing the change in permeability of said bands caused by said applied torque;
   - means for converting said sensed change in permeability to an electrical signal indicative of the magnitude of the torque applied to said member; and
   - indicator means responsive to said electrical signal for providing an indication that a predetermined torque has been applied to said fastener.

2. A tool, as claimed in claim 1, wherein each said band has at least one circumferential region which is free of residually unstressed areas over at least 80% of its circumferential length.

3. A tool, as claimed in claim 1, wherein each said band has at least one continuous circumferential region which is free of residually unstressed areas.

4. A tool, as claimed in claims 1, 2 or 3, wherein said region comprises the surface of said member.

5. A tool, as claimed in claims 1, 2 or 3 wherein said region is rigidly affixed to the surface of said member.

6. A tool, as claimed in claims 1, 2 or 3 wherein said region is formed of 18% Ni maraging steel.

7. A tool, as claimed in claims 1, 2 or 3 wherein the magnetic easy axes in said bands are oriented, respectively, at angles of ±20°-60° to the axis of said member.

8. A hand tool for applying torque to a fastener including fastener-engaging means, handle means to which torque is hand-applied and torque carrying means operatively coupled with said handle means and said fastener-engaging means for transmitting the hand-applied torque to the fastener, said torque carrying means comprising a member including a magnetoelastic torque transducer, ferromagnetic, magnetostrictive means associated with said member for altering in magnetic permeability in response to the application of torque to said member, means for applying a cyclically time varying magnetic field to said ferromagnetic magnetostrictive means, means for sensing the change in permeability caused by said applied torque, and means for converting said sensed change in permeability to an electrical signal indicative of the magnitude of the torque applied to said member, and indicator means responsive to said electrical signal for providing an indication that a predetermined torque has been applied to said fastener, the improvement comprising forming said ferromagnetic, magnetostrictive means from nickel maraging steel.

9. A tool, as claimed in claim 8, wherein said ferromagnetic, magnetostrictive means comprises of the surface of said member.

10. A tool, as claimed in claim 8, wherein said ferromagnetic, magnetostrictive means is rigidly affixed to the surface of said member.

11. A tool, as claimed in claims 8, 9 or 10 wherein said ferromagnetic, magnetostrictive means is formed of 18% Ni maraging steel.

12. A tool, as claimed in claims 8, 9 or 10 wherein said ferromagnetic, magnetostrictive means includes a pair of axially spaced-apart annular bands defined therewithin, said bands having respectively symmetrical right and left hand helically directed residual stress created magnetic anisotropy, each said band having at least one circumferential region which is free of residually unstressed areas over at least 50% of its circumferential length, said applying means applying said magnetic field to said bands, said sensing means sensing the change in permeability of said bands caused by said applied torque.

13. A tool, as claimed in claim 12, wherein each said band has at least one circumferential region which is free of residually unstressed areas over at least 80% of its circumferential length.

14. A tool, as claimed in claim 12, wherein each said band has at least one continuous circumferential region which is free of residually unstressed areas.

15. A tool, as claimed in claim 12, wherein the magnetic easy axes in said bands are oriented, respectively, at angles of ±20°-60° to the axis of said member.

16. A tool, as claimed in claim 8, wherein at least a portion of said ferromagnetic, magnetostrictive means is endowed with helically directed residual stress created magnetic anisotropy, at least one circumferential region of said portion being free of residually unstressed areas over at least 50% of its circumferential length, said applying means applying said magnetic field to said endowed portion and to an area of said member not so endowed, said sensing means sensing the permeability difference between said portion and said area resulting from the application of torque to said member, said converting means converting said sensed permeability difference to an electrical signal indicative of the magnitude of the applied torque.

17. A tool, as claimed in claim 16, wherein said circumferential region is free of residually unstressed areas over at least 80% of its circumferential length.

18. A tool, as claimed in claim 16, wherein said portion has at least one continuous circumferential region which is free of residually unstressed areas.

19. A hand tool for applying torque to a fastener including fastener-engaging means, handle means to which torque is hand-applied and torque carrying means operatively coupled with said handle means and said fastener-engaging means for transmitting the hand-applied torque to the fastener, said torque carrying means including a magnetoelastic torque transducer, said torque carrying means comprising a member having a ferromagnetic and magnetostrictive region, said transducer comprising:

a pair of axially spaced-apart annular bands defined within said region, said bands having respectively symmetrical right and left hand helically directed residual stress created, controlled magnetic anisotropy of sufficiently large magnitude compared with the random magnetic anisotropy in said member that the contribution to total magnetic anisotropy of any random anisotropy is negligible;

means for applying a cyclically time varying magnetic field to said bands;

means for sensing the change in permeability of said bands caused by said applied torque;

means for converting said sensed change in permeability to an electrical signal indicative of the magnitude of the torque applied to said member; and

indicator means responsive to said electrical signal for producing an indication that a predetermined torque has been applied to said fastener.

20. A tool, as claimed in claim 19, wherein said region is formed of nickel maraging steel.

21. A tool, as claimed in claims 19 or 20, wherein each said band has at least one circumferential region which is free of residually unstressed areas over at least 50% of its circumferential length.

22. A tool, as claimed in claim 21, wherein said circumferential region is free of residually unstressed areas over at least 80% of its circumferential length.

23. A tool, as claimed in claim 21, wherein each said band has at least one continuous circumferential region which is free of residually unstressed areas.

24. A tool, as claimed in claim 21, wherein said region comprises the surface of said member.

25. A tool, as claimed in claim 21, wherein said region is rigidly affixed to the surface of said member.

26. A tool, as claimed in claims 19 or 20, wherein said region comprises the surface of said member.

27. A tool, as claimed in claims 19 or 20, wherein said region is rigidly affixed to the surface of said member.

28. A tool, as claimed in claim 1, 8 or 19, including means for presetting the predetermined torque level at which said indicator means provides said indication.

29. A tool, as claimed in claim 1, 8 or 19, wherein said indicator means comprises audible indicator means.

30. A tool, as claimed in claim 1, 8 or 19, wherein said means for applying a cyclically time varying magnetic field includes multivibrator circuitry for producing a substantially square wave voltage signal.

* * * * *

D3

US005321985A

United States Patent [19]

Kashiwagi et al.

[11] Patent Number: 5,321,985

[45] Date of Patent: Jun. 21, 1994

[54] MAGNETOSTRICTION TYPE TORQUE SENSOR

[75] Inventors: Yoichiro Kashiwagi; Gen Sasaki; Hisashi Shiraki, all of Kariya; Kaneo Mohri, Nagoya, all of Japan

[73] Assignee: Kabushiki Kaisha Toyoda Jidoshokki Seisakusho, Kariya, Japan

[21] Appl. No.: 12,628

[22] Filed: Feb. 2, 1993

Related U.S. Application Data

[63] Continuation of Ser. No. 650,052, Feb. 4, 1991, abandoned.

[30] Foreign Application Priority Data

Feb. 7, 1990 [JP] Japan 2-27373

[51] Int. Cl.[5] G01L 3/02

[52] U.S. Cl. 73/862.335; 73/862.333; 73/DIG. 2; 324/209

[58] Field of Search ..... 73/862.333, 862.335, 73/862.336, 779, DIG. 2; 324/209

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Primary Examiner—Richard E. Chilcot, Jr.
Assistant Examiner—Elizabeth L. Dougherty
Attorney, Agent, or Firm—Brooks Haidt Haffner & Delahunty

[57] ABSTRACT

A magnetostriction type torque sensor has a magnetostrictive film formed on an outer peripheral surface of a rotary shaft, a coil having a coil centerline extending in a radial direction of the rotary shaft, and a signal processor responsive to coil impedance. Since the coil includes a coil centerline extending in a radial direction of the rotary shaft, magnetic fluxes are formed mainly in a radial direction of the rotary shaft. Accordingly, the magnetic fluxes intruding deep into the rotary shaft are decreased, and the rate of the magnetic fluxes passing through the magnetostrictive film is increased. As a result, the magnetostriction type torque sensor comes to have high sensitivity even when the rotary shaft has high magnetic permeability or high electric conductivity.

8 Claims, 9 Drawing Sheets

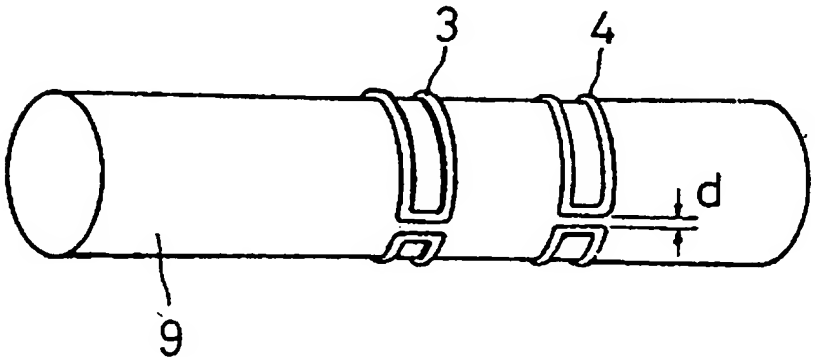


FIG. 1

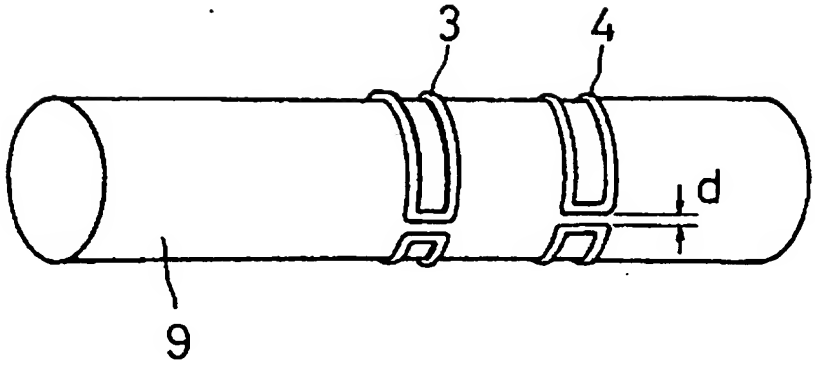


FIG. 2

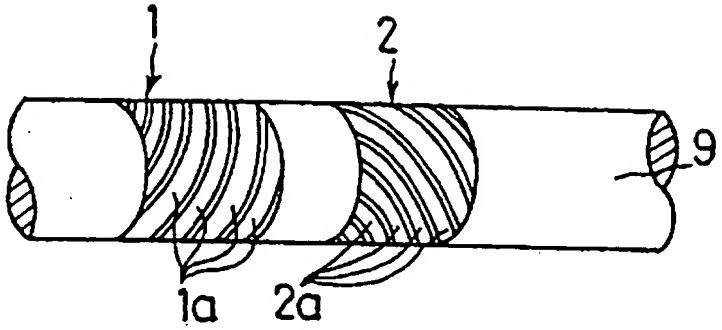
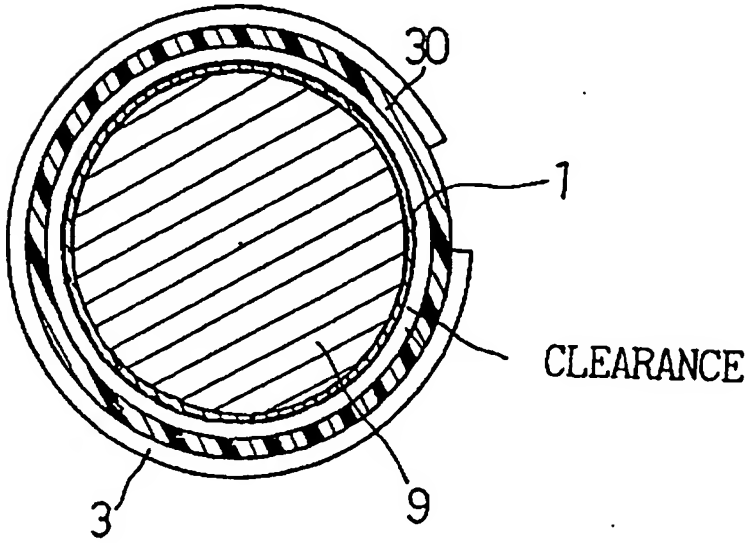


FIG. 3



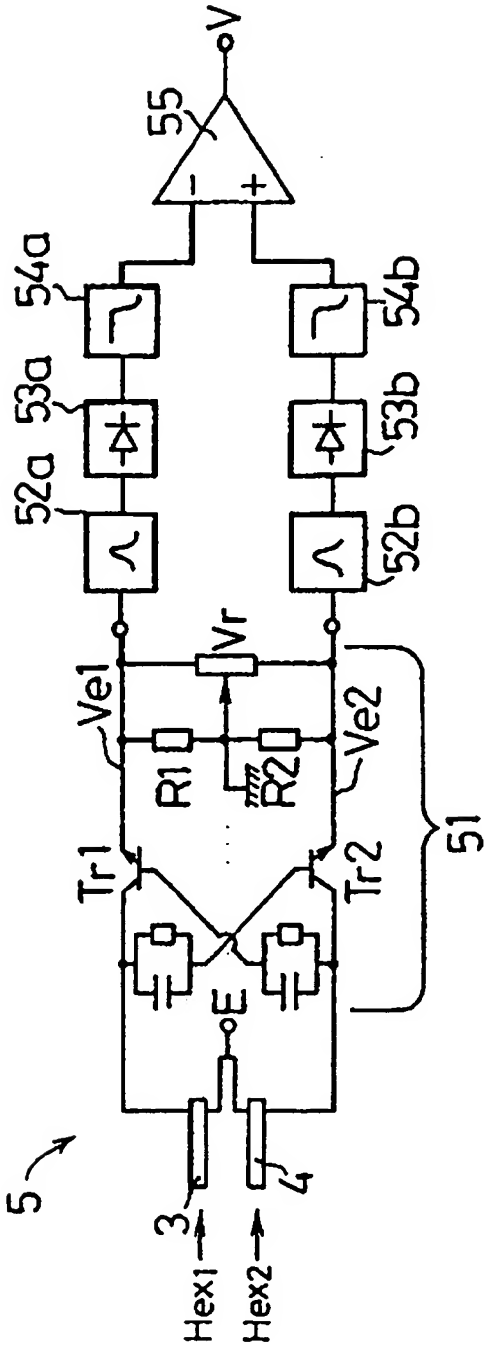

V
55
54a
54b
53a
53b
52a
52b
Vr
Ve1
Ve2
R1
R2
Tr1
Tr2
51
E
5
3
4
Hex1
Hex2

FIG. 4

FIG. 5

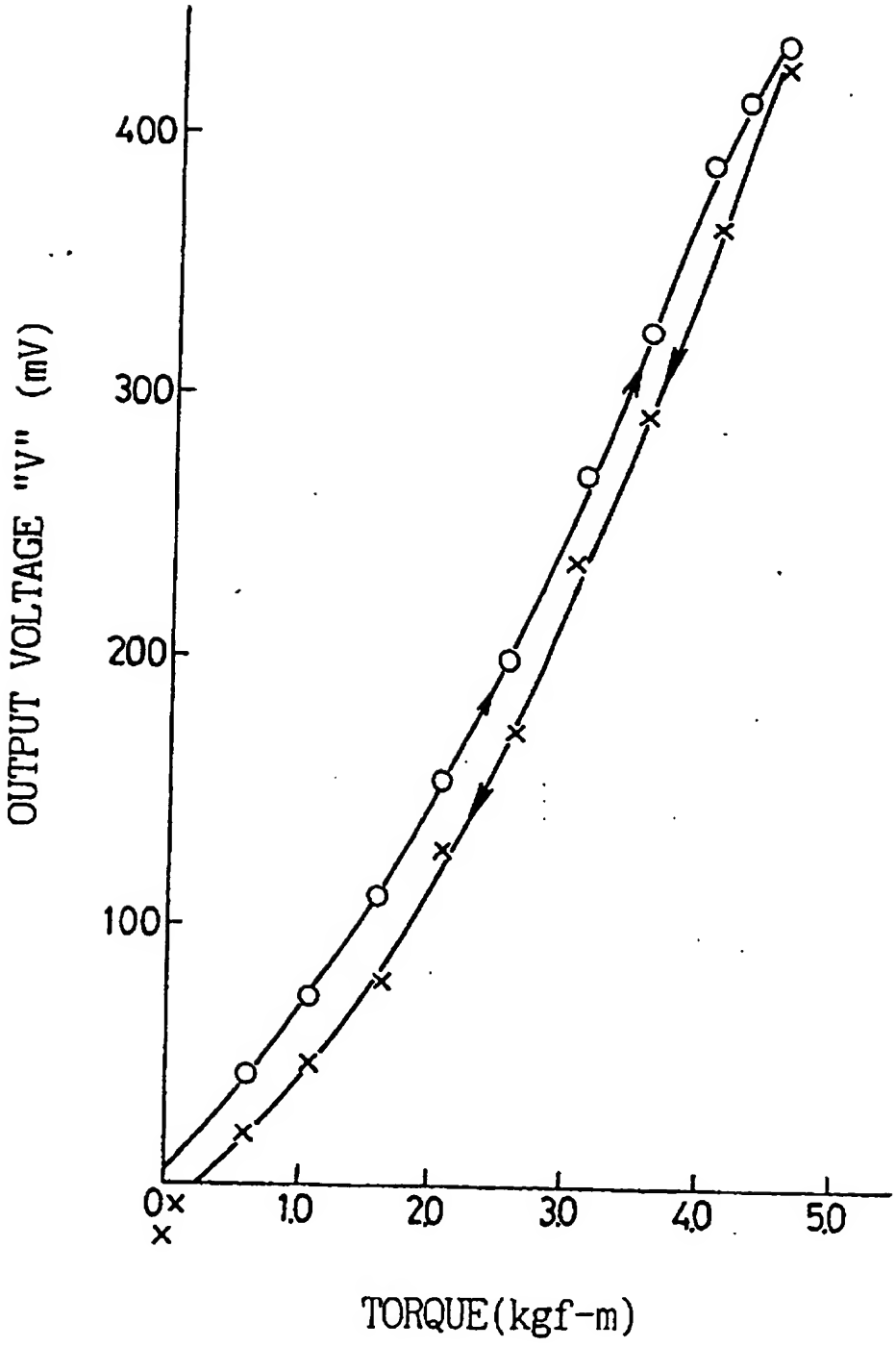


FIG. 6

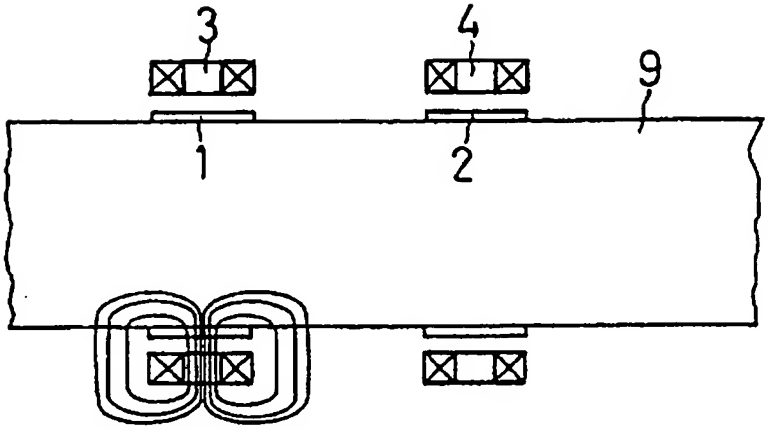


FIG. 7 (PRIOR ART)

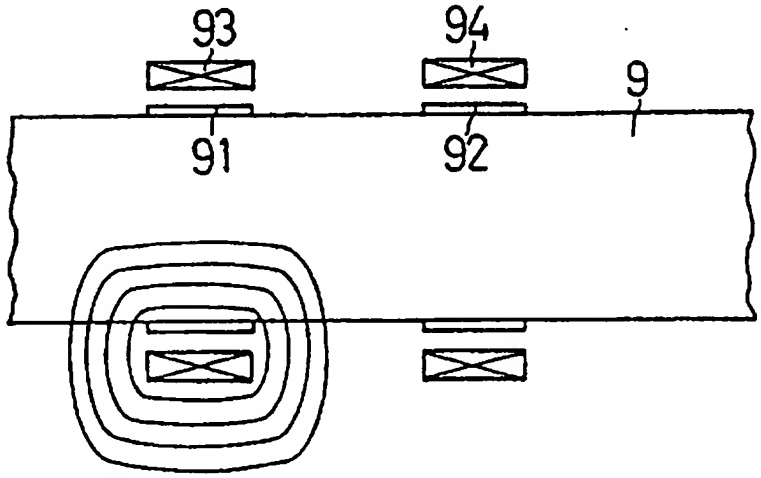


FIG. 8

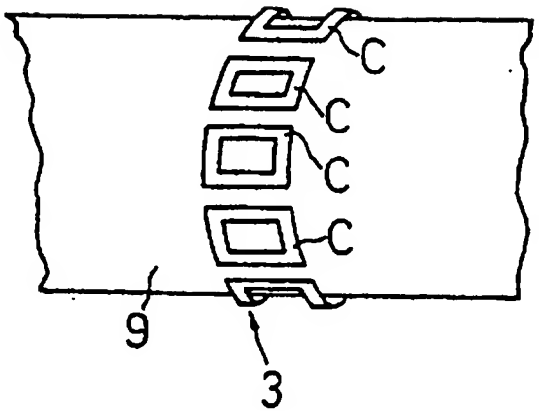


FIG. 9

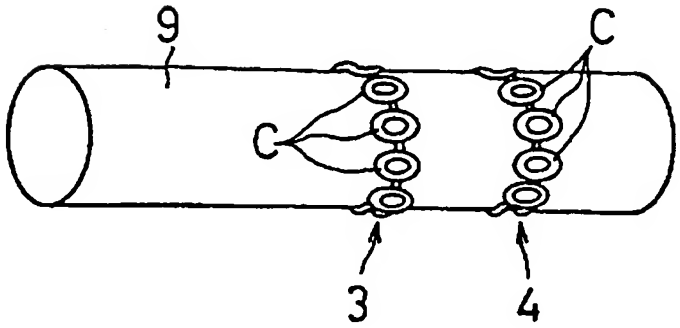


FIG. 10

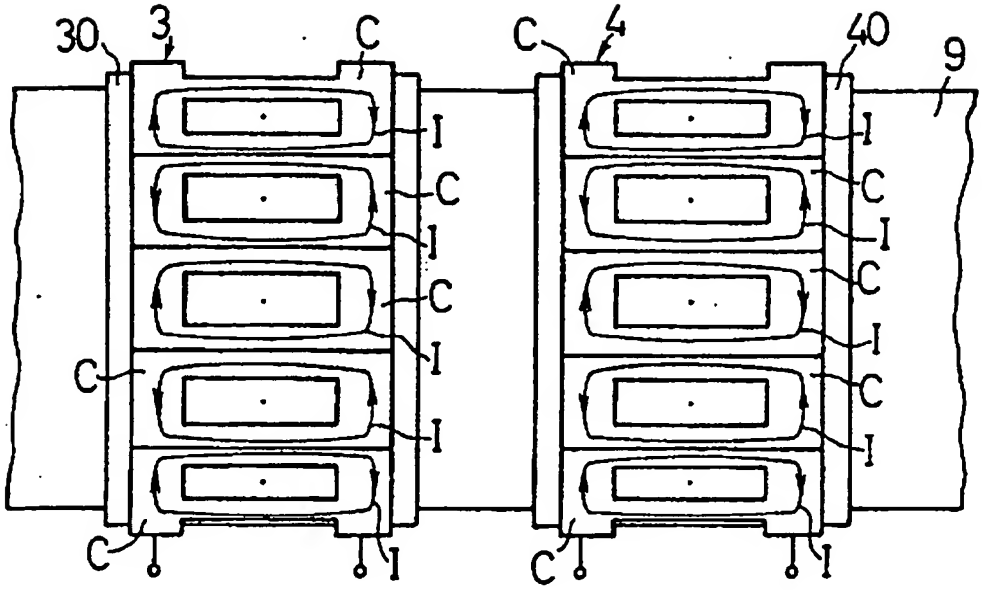


FIG. 11
(PRIOR ART)

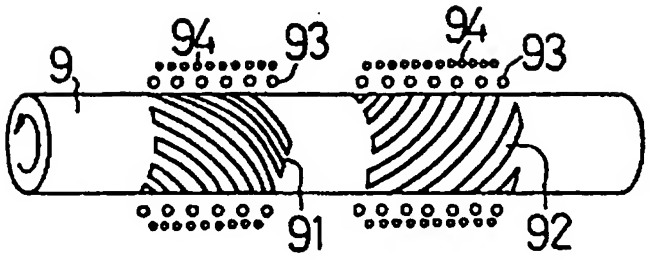


FIG.12

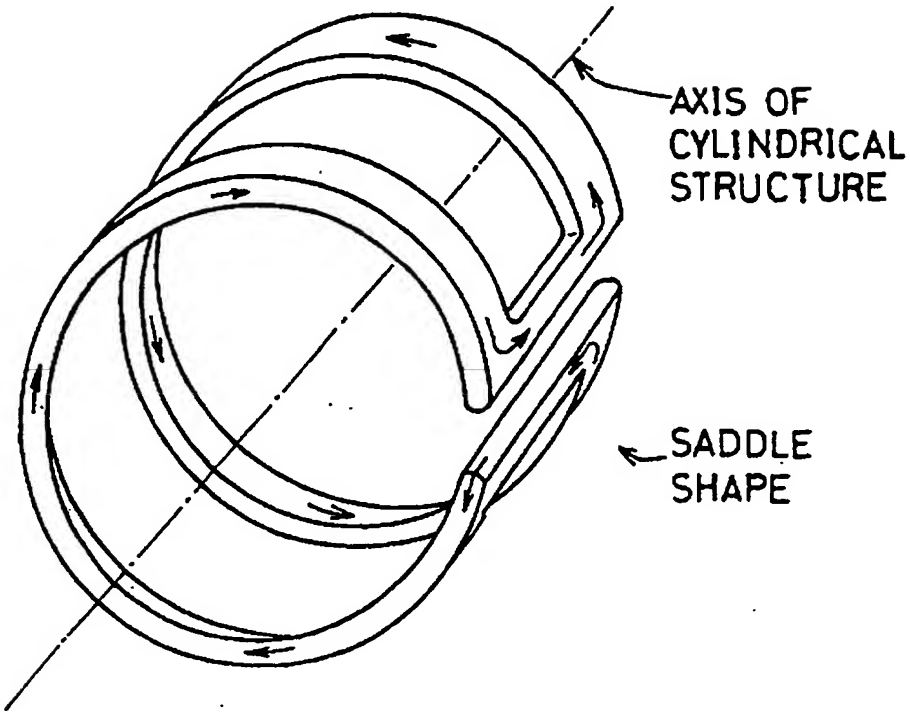
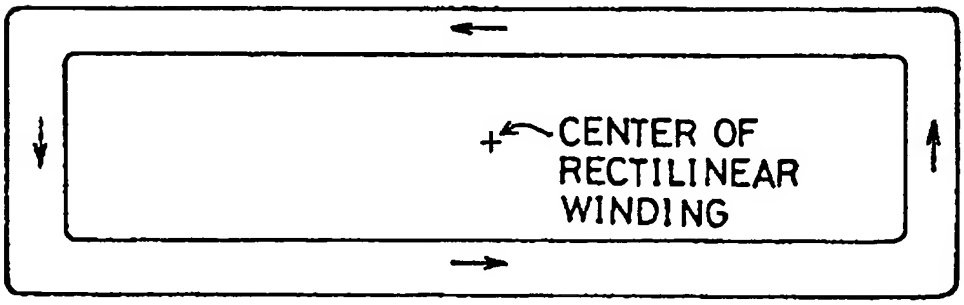

AXIS OF
CYLINDRICAL
STRUCTURE
SADDLE
SHAPE

FIG.13


CENTER OF
RECTILINEAR
WINDING

MAGNETOSTRICTION TYPE TORQUE SENSOR

This application is a continuation, of application Ser. No. 07/650,052, filed Feb. 4, 1991, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a magnetostriction type torque sensor.

2. Description of the Prior Art

FIG. 11 illustrates an example of prior art magnetostriction type torque sensors. The magnetostriction type torque sensor comprises magnetostrictive films 91 and 92 formed on outer peripheral surfaces of a rotary shaft 9, excitation coils 93 and 93 disposed around the rotary shaft 9 away from the magnetostriction films 91 and 92 by a predetermined distance in a radial direction, and detection coils 94 and 94 disposed on the excitation coils 93 and 93.

Configurational magnetic anisotropies are given to the configurations of the magnetostrictive films 91 and 92 so that the magnetostrictive films 91 and 92 are subjected to stresses acting in direction being opposite to each other. In a magnetic film having positive magnetostriction, for instance, in the magnetostrictive film 91 subjected to a tensile stress, the magnetic permeability of the magnetostrictive film 91 increases because of the inverse magnetostrictive effect. On the other hand, for instance, in the magnetostrictive film 92 subjected to a compression stress, the magnetic permeability of the magnetostrictive film 92 decreases because of the inverse magnetostrictive effect. Hence, the mutual inductances between the excitation coils 93 and the detection coils 94 vary in directions being opposite to each other when an alternating current is applied in the excitation coils 93 and 93, and accordingly the torques of the rotary shaft 9 can be detected from the output voltage differences between the detection coils 94 and 94.

However, when detecting the torques of a rotary shaft 9 made of iron, steel or the like having high magnetic permeability with the prior art magnetostriction type torque sensor, most of the mutual inductances between the excitation coils 93 and the detection coils 94 are generated by the rotary shaft 9 itself, and small mutual inductance components result from magnetic fluxes passing through the magnetostrictive films 91 and 92, namely most of the magnetic fluxes have passed through the rotary shaft 9. Hence, the variation rate of the mutual inductance resulting from the magnetic permeability variation of the magnetostrictive film 92 has been small. As a result, the prior art magnetostriction type torque sensor has been suffering from a problem of low detection sensitivity or S/N ratio (i.e., signal-to-noise ratio).

Likewise, when detecting the torques of a rotary shaft 9 made of iron, steel, aluminum alloy, titanium or the like having high electric conductivity with the prior art magnetostriction type torque sensor, the impedances of the excitation coils 93 decrease because of the eddy current loss resulting from alternating magnetic fluxes penetrating through the rotary shaft 9. Hence, the prior art magnetostriction type torque sensor has again exhibited deteriorated detection sensitivity or S/N ratio.

SUMMARY OF THE INVENTION

The present invention has been developed in order to solve the above-described problems. It is therefore an

object of the present invention to provide a magnetostriction type torque sensor having high sensitivity.

The above and other objects of the present invention can be achieved by a magnetostriction type torque sensor according to the present invention, the magnetostriction type torque sensor comprising:

a magnetostrictive film formed on an outer peripheral surface of a rotary shaft having at least high magnetic permeability or high electric conductivity;

an excitation coil for generating magnetic fluxes penetrating the magnetostrictive film, the excitation coil disposed on a peripheral surface being adjacent to the magnetostrictive film;

a detection coil disposed adjacent to the magnetostrictive film in a manner crossing with the magnetic fluxes, the detection coil including a coil center line extending in a radial direction of the rotary shaft; and

a signal processor for detecting torques of the rotary shaft from impedance variations of the detection coil.

The detection coil may be arranged so as to work both as the excitation coil and the detection coil.

The magnetostrictive film may be formed of an amorphous ribbon, a PVD (physical vapor deposition) film made of an Fe-Ni alloy, a plasma sprayed film made of an Fe-Ni alloy or the like.

The high magnetic permeability herein shall mean a relative magnetic permeability of 500 or more, and the high electric conductivity herein shall mean an electric conductivity of 100 micro-mho/cm or more.

When a torque is exerted on the rotary shaft, the magnetic permeability of the magnetostrictive film varies. As a result, the magnitude of the magnetostrictive film magnetization by the excitation coil, the number of magnetic flux lines linking with the detection coil, and the voltage between the both ends of the detection coil vary in this order.

In particular, since the centerline of the detection coil extends in a radial direction of the rotary shaft in the present invention, the magnetic fluxes are formed mainly in a radial direction of the rotary shaft. Accordingly, magnetic flux component passing through the magnetostrictive film is increased. Further, there arises a magnetic resistance influence (i.e., repellencies between the lines of the magnetic forces constituting the magnetic fluxes) and the skin effect. Hence, the magnetic fluxes intruding deep into the rotary shaft are decreased. As a result, the impedance component of the detection coil, resulting from the eddy current loss and the hysterisis loss in the rotary shaft, is decreased. Further, the inductance component of the detection coil, resulting from the magnetic fluxes passing through the rotary shaft but not passing through the magnetostrictive film, is also decreased.

Thus, the rate of the components, depending on the magnetic fluxes passing through the magnetostrictive film, with respect to the inductance of the detection coil is increased, and the inductance variation of the detection coil with respect to a predetermined magnetic permeability variation of the magnetostrictive film is increased. Eventually, the magnetostriction type torque sensor according to the present invention comes to have high sensitivity.

Further, even when the rotary shaft has the high magnetic permeability, the rate of the magnetic fluxes passing through the rotary shaft is decreased, and the magnetic modulation caused by magnetic heterogeneity is decreased. Hence, the magnetostriction type torque

sensor according to the present invention comes to have higher sensitivity or S/N ratio

Furthermore, even when the rotary shaft has the high electric conductivity, the impedance variation of the detection coil resulting from the eddy current loss in the rotary shaft is decreased, and the inductance variation of the detection coil with respect to a predetermined magnetic permeability variation of the magnetostrictive film is increased. Hence, the magnetostriction type torque sensor according to the present invention comes to have higher sensitivity or S/N ratio.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the present invention and many of its advantages will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings and detailed specification, all of which forms a part of the disclosure:

FIG. 1 is a plan view illustrating coils 3 and 4 employed by a magnetostriction type torque sensor of a First Preferred Embodiment according to the present invention;

FIG. 2 is a perspective view illustrating magnetostrictive films 1 and 2 employed by the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention;

FIG. 3 is a cross sectional view illustrating an arrangement of the coil B in a peripheral direction;

FIG. 4 is an electric circuit block diagram of a signal processor 5 employed by the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention;

FIG. 5 is a characteristic curve illustrating the relationship between output voltages "V" and torques exhibited by the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention;

FIG. 6 is a schematic diagram illustrating a distribution of magnetic fluxes exhibited by the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention;

FIG. 7 is a schematic diagram illustrating a distribution of magnetic fluxes exhibited by a conventional magnetostriction type torque sensor.

FIG. 8 is a perspective view illustrating a magnetostriction type torque sensor of a Third Preferred Embodiment according to the present invention;

FIG. 9 is a perspective view illustrating a magnetostriction type torque sensor of a Fourth Preferred Embodiment according to the present invention;

FIG. 10 is a plan view illustrating coils 3 and 4 employed by a magnetostriction type torque sensor of a Second Preferred Embodiment according to the present invention;

FIG. 11 is a perspective view of a conventional magnetostriction type torque sensor;

FIG. 12 is a perspective view of a coil employed in the embodiment of FIG. 1 but removed from the shaft; and

FIG. 13 is a development view of the coil of FIG. 12.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Having generally described the present invention, a further understanding can be obtained by reference to the specific preferred embodiments which are provided herein for purposes of illustration only and are not intended to limit the scope of the appended claims.

First Preferred Embodiment

The magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention will be hereinafter described with reference to FIGS. 1 through 4.

The magnetostriction type torque sensor comprises magnetostrictive films 1 and 2 (Not shown in FIG. 1, see FIG. 2.) formed on outer peripheral surfaces of a rotary shaft 9, coils 3 and 4 working both as the excitation coil and the detection coil and disposed adjacent to the magnetostrictive films 1 and 2, and a signal processor 5 (See FIG. 4.) for detecting the differences between the self-inductances of the coils 3 and 4.

The rotary shaft 9 is made of a carbon steel rod having a diameter of 2 cm. The magnetostrictive films 1 and 2 are made of a sputtered film comprising 40% by weight of Fe and 60% by weight of Ni, and formed in a size of approximately 10 micrometers in film thickness and 4 mm in width. As illustrated in FIG. 2, the magnetostrictive film 1 is formed to have a left lead angle of 45 degrees with respect to the central axis of the rotary shaft 9 and to include a plurality of band films 1*a* disposed obliquely at predetermined intervals, and the magnetostrictive film 2 is formed to have a right lead angle of 45 degrees with respect to the central axis of the rotary shaft 9 and to include a plurality of band films 2*a* disposed obliquely at predetermined intervals. The band films 1*a* and 2*a* are designed to have a width of 3 mm, and the intervals between the neighboring band films 1*a* and the intervals between the neighboring band films 2*a* are designed to have a width of 1 mm.

The coils 3 and 4 are independently disposed on outer peripheral surfaces of coil bobbins 30 and 40 (Not shown in FIG. 1, see FIG. 3.) in a saddle-like configuration. As illustrated in FIG. 3, the coil bobbins 30 and 40 are made of a resin, and disposed around the rotary shaft 9 away from the magnetostrictive films 1 and 2 by a small clearance. The coils 3 and 4 are wound 200 turns, and have a coil width of 20 mm in an axial direction, respectively. Further, a clearance "d" (See FIG. 1.) in a peripheral direction is designed to be 2 mm, and clearances between the coils 3 and the magnetostrictive film 1 and clearances between the coils 4 and the magnetostrictive film 2 are designed to be 1 mm.

The coils 3 and 4 are identical. In order to better understand the terminology used herein, reference should be had to FIG. 12 showing in perspective the coil 3 removed from the shaft 9. The small arrows indicate the path followed by the wire constituting the winding of the coil. While not shown, the ends of the wire are brought out for connection to the detection circuit described below. As clearly seen in FIG. 12, the coil structure is saddle shape, having been formed into a cylindrical configuration about an axis identified as the "AXIS OF CYLINDRICAL STRUCTURE." If the coil 3 were to be developed, the development would appear as a rectangle as shown in FIG. 13. It should be obvious that the wire windings of the coil, following the small arrows, encircle a center which has been identified as the "CENTER OF RECTILINEAR WINDING." The imaginary line passing through that "center" normal to the plane of the paper is referred to herein as the centerline of the coil. It can be thought of as the magnetic axis of the coil, a center of magnetic symmetry.

With reference to FIG. 4, the signal processor 5 will be hereinafter described along with the operation of the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention. The signal processor 5 comprises a dual magnetic core multivibrator type oscillator circuit 51, tuning amplifiers 52*a* and 52*b*, detection circuits 53*a* and 53*b*, low-pass filters 54*a* and 54*b* and a differential amplifier 55.

Two (2) input terminals of the oscillator circuit 51 are connected to one ends of the coils 3 and 4, and the other end of the coils 3 and 4 are connected to a high voltage electric power source "E". The oscillator circuit 51 includes an astable multivibrator employing transistors "Tr1" and "Tr2." The coils 3 and 4 constitute collector loads of the transistors "Tr1" and "Tr2" independently. The emitters of the transistors "Tr1" and "Tr2" are grounded by way of emitter resistors "R1" and "R2" independently, and are also grounded by way of a 3-terminal sliding resistor "Vr."

The oscillator circuit 51 oscillates at a predetermined frequency "f1" in a pulsating manner, and pulsating currents are applied to the collectors of the transistors "Tr1" and "Tr2." The internal stresses of the rotary shaft 9 vary the magnetic permeabilities of the magnetostrictive films 1 and 2 in opposite directions, namely one in an increasing direction and the other in a decreasing direction, thereby modulating the self-inductances of the coils 3 and 4. As a result, both of the collector currents, i.e., pulsating currents, undergo an amplitude modulation because of the magnetic permeability variations of the magnetostrictive films 1 and 2. Both of the collector currents subjected to the amplitude modulation vary the emitter voltages "Ve1" and "Ve2" when flowing over the emitter resistors "R1" and "R2." Here, the 3-terminal sliding resistor "Vr" is a resistor for adjusting the zero point.

The emitter voltages "Ve1" and "Ve2" are amplified around the frequency "f1" (i.e., the center frequency) by the tuning amplifiers 52*a* and 52*b*. The output voltages from the tuning amplifiers 52*a* and 52*b* are then detected by the detection circuits 53*a* and 53*b*, and the components of the carrier wave frequency "f1" in the detected voltages are out independently by the low-pass filters 54*a* and 54*b*. Finally, the differences between the output voltages from the low-pass filter 54*a* and the output voltages from the low-pass filter 54*b* are amplified by the differential amplifier 55, and made into an output voltage "V."

A characteristic curve, illustrating the relationship between the output voltages "V" thus obtained and the torques of the rotary shaft 9, is illustrated in FIG. 5. When obtaining the characteristic curve, the carrier wave frequency "f1" and the electric current applied to the coils 3 and 4 are designed to be 34 KHz and 100 mA in the signal processor 5 respectively, and accordingly the overall amplification factor of the signal processor is designed to be 40 dB.

A schematic diagram illustrating a distribution of magnetic fluxes exhibited by the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention is illustrated in FIG. 6, and a schematic diagram illustrating a distribution of magnetic fluxes exhibited by the conventional magnetostriction type torque sensor (See FIG. 11.) is illustrated in FIG. 7. It is apparent from FIGS. 6 and 7 that the magnetic fluxes extend mainly in an axial direction of the rotary shaft 9 in the conventional magnetostriction type torque sensor, and that the magnetic fluxes extend mainly in a radial direction of the rotary shaft 9 in the magnetostriction type torque sensor of the First Preferred Embodiment.

Hence, the magnetic fluxes are localized on the peripheral portions of the rotary shaft 9 in the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention. As a result, the impedance variations of the coils 3 and 4 are increased, thereby achieving a high sensitivity. The impedance variations result from the magnetic permeability variations of the magnetostrictive films 1 and 2 caused by the internal stresses of the rotary shaft 9.

Second Preferred Embodiment

Modified versions of the magnetostriction type torque sensor of the First Preferred Embodiment according to the present invention will be hereinafter described with reference to FIGS. 8 through 10. The configurations and dispositions of the coils 3 and 4 are modified in the following preferred embodiments, but the arrangements of the other constituents are identical with those of the First Preferred Embodiment

The magnetostriction type torque sensor of the Second Preferred Embodiment according to the present invention will be hereinafter described. Turning now to FIG. 10, the coil 3 of the magnetostriction type torque sensor includes twelve (12) unit coils "C" disposed in rotation symmetry and connected in series. The unit coils "C" contacting and neighboring are wound in directions being opposite to each other as indicated by the directions of electric current shown in FIG. 10. The coil 4 has an arrangement equivalent thereto. Naturally, the coil centerlines of the unit coils "C" extend in a radial direction of the rotary shaft 9. In the magnetostriction type torque sensor of the Second Preferred Embodiment, the unit coils "C" constituting the coils 3 and 4 may be collectively wound on coil bobbins 30 and 40 in an overlapping winding manner or a wave winding manner, such as a coil winding manner in a motor.

Since the magnetostriction type torque sensor of the Second Preferred Embodiment according to the present invention thus arranged operates and effects advantages similarly to the First Preferred Embodiment, the operation thereof will not be described herein.

Third Preferred Embodiment

Turning now to FIG. 8, the magnetostriction type torque sensor of the Third Preferred Embodiment according to the present invention will be hereinafter described. As illustrated in FIG. 8, there are provided clearances between the unit coils "C" neighboring each other in a peripheral direction in the magnetostriction type torque sensor of the Third Preferred Embodiment. In the magnetostriction type torque sensor of the Third Preferred Embodiment, the coil center lines of the unit coils "C" naturally extend in a radial direction of the rotary shaft 9, but it is not necessary to wind the unit coils "C" neighboring each other in directions opposite to each other.

Since the magnetostriction type torque sensor of the Third Preferred Embodiment according to the present invention thus arranged operates and effects advantages similarly to the First Preferred Embodiment, the operation thereof will not be described herein.

Fourth Preferred Embodiment

As illustrated in FIG. 9, the unit coils "C" of the coils 3 and 4 are formed in a circular shape in the magneto-

striction type torque sensor of the Fourth Preferred Embodiment. Also in the magnetostriction type torque sensor of the Fourth Preferred Embodiment, the coil center lines of the unit coils "C" naturally extend in a radial direction of the rotary shaft 9.

Since the magnetostriction type torque sensor of the Fourth Preferred Embodiment according to the present invention thus arranged operates and effects advantages similarly to the First Preferred Embodiment, the operation thereof will not be described herein.

Having now fully described the present invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the present invention as set forth herein including the appended claims.

What is claimed is:

1. A magnetrostriction type torque sensor comprising in combination:

a magnetostrictive film formed over a given surface area on an outer peripheral surface of a rotary shaft formed from a material having at least high magnetic permeability or high electric conductivity;

a coil having a centerline about which its windings are wound to form said coil, said coil being disposed adjacent said magnetostrictive film with said centerline oriented radially relative to said rotary shaft, said coil being provided with a cylindrical curvature but being non-helical and disposed substantially concentric with but radially spaced substantially uniformly from said peripheral surface of said shaft; and

impedance measuring means including a source of alternating current coupled to said coil for providing a torque proportional signal output responsive to variations in the impedance of said coil resulting from shaft torque induced variation in permeability of said magnetostrictive film.

2. A magnetostrictive type torque sensor according to claim 1, wherein said coil is wider in the circumferential direction of said shaft than in the axial direction of said shaft.

3. A magnetostrictive type torque sensor according to claim 1, wherein said given surface area extends completely around said shaft and said coil extends circumferentially more than half way around the periphery of said magnetostrictive film.

4. A magnetostrictive type torque sensor according to claim 1, wherein said coil has a rectilinear shape when viewed radially of said shaft with two sides extending circumferentially relative to said shaft.

5. A magnetostrictive type torque sensor according to claim 1, wherein said given surface area extends completely around said shaft, and said coil extends circumferentially substantially entirely about said shaft, and extends in the shaft axial direction substantially extensively with said given surface area.

6. A magnetostrictive type torque sensor comprising in combination:

a magnetostrictive film formed over a given surface area on an outer peripheral surface of a rotary shaft formed from a material having at least high magnetic permeability or high electric conductivity;

a coil having a centerline about which its windings are wound to form said coil, said coil being disposed adjacent said magnetostrictive film with said centerline oriented radially relative to said rotary shaft, said coil being provided with a cylindrical curvature but being non-helical and disposed substantially concentric with but radially spaced substantially uniformly from said peripheral surface of said shaft; and

impedance measuring means including a source of alternating current coupled to said coil for providing a torque proportional signal output responsive to variations in the impedance of said coil resulting from shaft torque induced variation in permeability of said magnetostrictive film,

said coil including a plurality of unit coils connected in series and disposed in a cylindrical array with adjacent unit coils in side by side contact and wound in opposite directions.

7. A magnetostrictive type torque sensor according to claim 6, wherein said given surface area extends completely around said shaft, and said coil extends circumferentially substantially entirely about said shaft, and extends in the shaft axial direction substantially coextensively with said given surface area.

8. A magnetostrictive type torque sensor comprising in combination:

a magnetostrictive film formed over a given surface area on an outer peripheral surface of a rotary shaft formed from a material having at least high magnetic permeability or high electric conductivity;

a coil having a centerline about which its windings are wound to form said coil, said coil being disposed adjacent said magnetostrictive film with said centerline oriented radially relative to said rotary shaft, said coil being provided with a cylindrical curvature but being non-helical and disposed substantially concentric with but radially spaced substantially uniformly from said peripheral surface of said shaft; and

impedance measuring means including a source of alternating current coupled to said coil for providing a torque proportional signal output responsive to variations in the impedance of said coil resulting from shaft torque induced variation in permeability of said magnetostrictive film,

said given surface area extending completely around said shaft, and said coil consisting of a single saddle-shaped winding substantially completely encircling said shaft.

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(54) Torque sensor.

(57) In a torque sensor of a noncontact type, a pair of amorphous magnetic ribbons (12, 13) are bonded to a shaft (11) to which a rotary torque is applied. A pair of coils (28, 29) are wound around the shaft (11) and an alternative magnetic field is applied from the coils (28, 29) to the magnetic ribbons (12, 13) along the axis of the shaft (11). A permanent magnet (23) and yokes (19, 21) are located around the shaft (11) and a bias magnetic field is also applied from the magnet (23) to the magnetic ribbons (12, 13) through the yokes (19, 21).

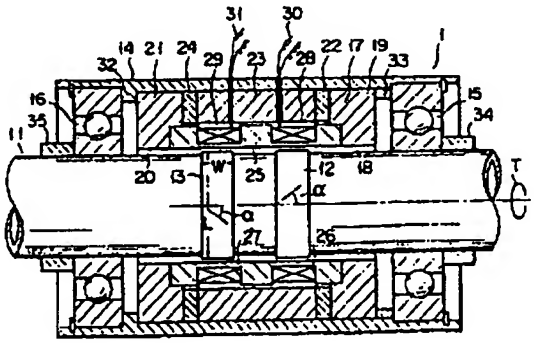

FIG. 1

EP 0 366 217 A2

Torque sensor

The present invention relates to a torque sensor for sensing a torque applied to a shaft, by utilizing a magnetostriction effect.

Various types of torque sensors for sensing a torque applied a shaft (hereinafter, called "shaft torque") are well known. For example, USP 4,627,298 (Sahashi et al.) discloses a torque sensor utilizing a magnetostriction effect of a magnetic metallic ribbon having an induced magnetic anisotropy, Japanese Patent Publication (Kokoku) No. 62-28413 discloses a torque sensor employing an amorphous magnetic metallic ribbon as a magnetic metallic ribbon and utilizing a magnetostriction effect of the amorphous magnetic metallic ribbon. In this type of torque sensor utilizing a magnetostriction effect of a magnetic metallic ribbon, a magnetic metallic ribbon having a large magnetostriction effect is fixed on the outer periphery a rotating shaft, and a coil is arranged near the metallic ribbon such that the coil does not contact the shaft. The permeability of the magnetic metallic ribbon, which is caused by a torque applied to the shaft, is changed. A resultant change in impedance of the coil or a change in induced voltage is detected. Based on the detection signal, the shaft torque is sensed. Thus, the torque can be sensed without bringing the sensor into contact with the shaft, and the sensor can be provided on a shaft which is already assembled in an apparatus. In addition, the direction of the torque applied to the shaft can easily be detected by suitably arranging on the shaft two or more magnetic metallic ribbons having induced magnetic anisotropy.

However, this type of torque sensor utilizing the magnetostriction effect of the magnetic metallic ribbon has the following problem. That is, the torque can be accurately sensed in a space free from an external magnetic field, e.g., in a laboratory. However, in a space having an external magnetic field which is variable, the sensitivity of detection varies depending on the external magnetic field. Thus, the torque cannot be sensed exactly. In addition, in the case where the shaft is made of a ferromagnetic body, the shaft is magnetized by the external magnetic field or a magnetic field produced by the coil of the torque sensor, and the magnetization of the shaft deteriorates the sensitivity of detection.

An object of the present invention is to provide a torque sensor which can maintain high detection sensitivity and can always sense a torque accurately.

Another object of the invention is to provide a torque sensor which can always sense a torque accurately with high detection sensitivity and with no influence from an external magnetic field.

Still another object of the invention is to provide a torque sensor which can always sense a torque accurately with high detection sensitivity, even if a shaft to be subjected to torque detection is made of a magnetic material.

The present invention can provide a torque sensor of a noncontact type for sensing a rotary torque applied to a shaft having an axis, the sensor comprising:

a first magnetic ribbon bonded to the shaft along the circumferential direction of the shaft, said ribbon comprising a magnetic material having an induced magnetic anisotropy in a direction of an angle α in respect to the axis of the shaft;

means for generating an alternative magnetic field along the shaft and applying the magnetic field to said magnetic ribbon;

means for generating a constant biasing magnetic field along the shaft and applying the biasing magnetic field to said magnetic ribbon; and

means for detecting the magnetic fields passing through said magnetic ribbon to generate an output signal.

Further, this invention provides a torque sensor of a noncontact type for sensing a rotary torque applied to a shaft having an axis, the sensor comprising:

a first amorphous magnetic ribbon bonded to the shaft along the circumferential direction of the shaft, said ribbon comprising a magnetic material having an induced magnetic anisotropy in a direction of an angle α in respect to the axis of the shaft;

means for generating an alternative magnetic field along the shaft and applying the magnetic field to said magnetic ribbon;

means for generating a constant biasing magnetic field along the shaft and applying the biasing magnetic field to said magnetic ribbon; and

means for detecting the magnetic fields passing through said magnetic ribbon to generate an output signal.

Furthermore, this invention provides a torque sensor of a noncontact type for sensing a rotary torque applied to a shaft which has an axis and is made of a magnetic material, the sensor comprising:

a first magnetic ribbon bonded to the shaft along the circumferential direction of the shaft, said ribbon comprising a magnetic material having an induced magnetic anisotropy in a direction of an angle α in respect to the axis of the shaft;

a second magnetic ribbon arranged close to said first magnetic ribbon and bonded to the shaft along

the circumferential direction of the shaft, said second ribbon comprising a magnetic material having an induced magnetic anisotropy in a direction of an angle $-\alpha$ in respect to the axis of the shaft;
means for generating an alternating magnetic field along the shaft and applying the magnetic field to said magnetic ribbon;
means for generating a constant biasing magnetic field along the shaft and applying the biasing magnetic field to said magnetic ribbon; and
means for detecting the magnetic fields passing through said magnetic ribbon to generate an output signal.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 shows a vertical cross section of a detection section of a torque sensor according to an embodiment of the present invention;

Fig. 2 shows a circuit structure of a signal processing section connected to the detection section shown in Fig. 1;

Fig. 3 is a graph showing the relationship between a torque and an output in the sensor shown in Figs. 1 and 2;

Fig. 4 is a graph showing the relationship between the intensity of a DC biasing magnetic field and a torque detection sensitivity;

Fig. 5 is a vertical cross section of a detection section of a torque sensor according to another embodiment of the invention; and

Fig. 6 shows a circuit structure of a signal processing section connected to the detection section shown in Fig. 5.

Fig. 1 shows detection section 1 of a torque sensor according to an embodiment of the present invention, and Fig. 2 shows signal processing section 2 connected to detection section 1. In Fig. 1, shaft 11 for transmitting a torque is made of a ferromagnetic material in a cylindrical shape. A pair of amorphous magnetic metallic ribbons 12 and 13 are bonded to shaft 11 around its outer periphery. First ribbon 12 has a uniaxial magnetic anisotropy. The direction of the magnetic anisotropy of first ribbon 12 is inclined to the axis of shaft 11 by an angle α. Similarly, second ribbon 13 has a uniaxial magnetic anisotropy. The direction of the magnetic anisotropy of second ribbon 12 is inclined to the axis of shaft 11 by an angle $-\alpha$.

Shaft 11 is inserted into non-magnetic cylindrical housing 14 which is fixed on a stationary base. Amorphous magnetic metallic ribbons 12 and 13 are arranged in a space within housing 14. Shaft 11 is supported by bearings 15 and 16 are arranged at both end portions of the inner surface of housing 14. Biasing magnetic field applying source 17 for applying a biasing magnetic field along shaft 11 is fixed in a space within housing 14 which is defined by bearings 15 and 16. Biasing magnetic field applying source 17 comprises ferromagnetic ring-shaped yokes 19 and 21, ferromagnetic cylindrical yoke 23, and ring-shaped permanent magnets 22 and 24. Yokes 19 and 21 have pole-faces 18 and 20 which face the peripheral surface of shaft 11. Permanent magnets 22 and 14 and yoke 23 are arranged between a side face of a peripheral part of yoke 19 and a side face of a peripheral part of yoke 21. Permanent magnets 22 and 24 are magnetized in a direction along the axis of shaft 11. In biasing magnetic field applying source 17, a magnetic flux generated from ring-shaped permanent magnets 22 and 24 passes through any one of yokes 19, 21 and 23 and one of pole-faces 18 and 20, flows through shaft 11, and crosses amorphous magnetic metallic ribbons 12 and 13. Then, the magnetic flux returns to permanent magnets 22 and 24 through the other of pole-faces 18 and 20 and any of yokes 19, 21 and 23. Non-magnetic cylindrical coil bobbin 25 is clamped in the axial direction between a side face of an inner part of yoke 19 and a side face of an inner part of yoke 21. Circumferentially extending grooves 26 and 27 are formed in the outer peripheral surface of coil bobbin 25. Coils 28 and 29, which have the same number of windings and generated an alternating magnetic field for torque detection along shaft 11, are mounted in grooves 26 and 27. Coils 28 and 29 face amorphous magnetic metallic ribbons 12 and 13. Line terminals 30 and 31 of coils 28 and 29 are led to the outside through holes made in yokes 23 and housing 14. Yokes 19, 21 and 23, permanent magnets 22 and 24, coil bobbin 25, and coils 28 and 29 are fixed within housing 14 such that these elements are immovable in the axial direction in the following manner. At first, yoke 21 is engaged with engaging projection 32 formed on the inner face of housing 14. Then, permanent magnet 24 is mounted. Thereafter, coil bobbin 25 having coils 28 and 29 and yoke 23 having holes, into which line terminals 30 and 31 are inserted, are mounted within housing 14. Permanent magnet 22 and yoke 19 are mounted within housing 14. Finally, an outer race of bearing 15 is fixed on housing 14 via spacer 33 are guided to the outside through the hole of housing 14. In Fig. 1, reference numerals 34 and 35 indicate stop rings for fixing inner races of bearings 15 and 16.

As shown in Fig. 2, in signal processing section 2, a bridge circuit is constituted by coils 28 and 29 and resistors 41 and 42. Input terminals of the bridge circuit are connected through variable resistors 43 and 44 for balance adjustment and switch 52 to an output terminal of AC oscillator 45 for producing a high frequency voltage signal of, for example, 100 KHz. A node between coil 28 and

resistor 41 and a node between coil 29 and resistor 42 are connected to differential amplifier 46. Thus, midpoint potentials of the bridge circuit are input to differential amplifier 46, and an output of differential amplifier 46 is supplied to synchronized detector 47. A high-frequency power source voltage generated from power source 45 is supplied, as a reference wave, to phase signal setting device or synchronized signal generator 48. A reference phase signal supplied from phase signal setting device 48 is sent to synchronized detector 47. Synchronized detector 47 detects and rectifies an output of differential amplifier 46 with the use of the reference phase signal. An output of synchronized detector 47 is smoothed by filter 49 and is output as DC output V0.

The operation of the torque sensor having the above structure will now be described.

Resistors 43 and 44 are preadjusted so that the output amplitude of differential amplifier 46 decreases to a minimum. When torque T is applied to shaft 11, amorphous magnetic metallic ribbons 12 and 13 on shaft 11 are distorted by the influence of torque T. As a result, the magnetic permeability of ribbons 12 and 13 is changed by the magnetostriction effect. As stated above, ribbons 12 and 13 have uniaxial magnetic anisotropy which facilitates magnetization in directions inclined by α and $-\alpha$ in respect to the axis of shaft 11. In the case where the angle α is about 45 , when torque T is applied to shaft 11, the axis of easy magnetization is changed to the direction of surface stress produced in shaft 11 by torque T. As shown in Fig. 1, when torque T is applied to shaft 11, a tensile stress is produced in ribbon 12 and a compressive stress is produced in ribbon 13. Thus, the magnetostriction effect is efficiently brought about in ribbons 12 and 13, so that the magnetic permeability of ribbon 12 increases and the magnetic permeability of ribbon 13 decreases. In accordance with a variation in permeability, the impedances of coils 28 and 29 change. As a result, as shown in Fig. 3, the output V0 of signal processing section 2 changes depending on the intensity and direction of torque T, and the torque applied to shaft 11 is sensed. The principle of detection in this type of torque sensor is described in detail in USP 4,627,298 (Sahashi, et al.).

The torque sensor shown in Fig. 1 is provided with biasing magnetic field applying source 17 which uses permanent magnets 22 and 24 as a magnetic field generation source. Since both permanent magnets 22 and 24 are magnetized along the shaft, the magnetic flux of permanent magnets 22 and 24 flows through a path including magnet 22, yoke 19, pole-face 18, shaft 11, pole-face 20, yoke 21, magnet 24, yoke 23 and permanent magnet 19. Thus, a DC biasing magnetic field, as well as a torque detection magnetic field, is applied to ribbons 12 and 13. The inventors confirmed by experiments that the application of a DC biasing magnetic field can keep the detection sensitivity at a constant value. Namely, the dimensions of ribbons 12 and 13 are determined such that the width W of each of ribbons 12 and 13 in the axial direction of shaft 11 is set to be smaller than the length L of each of ribbons 12 and 13 in the circumferential direction of shaft 11 ($W < L$). Fig. 4 shows variations in torque detection sensitivity for torque T of a torque sensor, in which shaft 11 is formed of a ferromagnetic material or carbon steel for mechanical structure (JIS S45C) so as to have a diameter of 25 mm, when the intensity of the DC biasing magnetic field applied to ribbons 12 and 13 is changed. In Fig. 4, the abscissa indicates the intensity of the DC biasing magnetic field, and the ordinate indicates the torque detection sensitivity calculated in terms of the value of the signal input to differential amplifier shown in Fig. 2. As seen from Fig. 4, when the intensity and direction of the DC biasing magnetic field are changed, the torque detection sensitivity changes. Also, when the voltage applied to the bridge circuit is changed, the torque detection sensitivity changes. As shown in Fig. 4, when the intensity of the biasing magnetic field is close to zero, i.e., -10 to 30 Oe, the torque detection sensitivity changes greatly. In the case where an external disturbance magnetic field is applied as a biasing magnetic field, or shaft 11 is magnetized by an excessive current produced at the time of the operation of switch 52, the torque detection sensitivity of the torque sensor changes. In other words, even if the same torque is applied to shaft 11, the torque sensor produces detection outputs of different levels, which indicate that different torques are applied to shaft 11. On the other hand, as seen from Fig. 4, when a DC biasing magnetic field having an intensity of 40 Oe or above, the torque detection sensitivity is substantially constant and stable. In this case, if the intensity of the DC biasing magnetic field is set to -40 Oe or thereabouts, the torque detection sensitivity is unchanged even if an external magnetic field is applied or shaft 11 is magnetized. In Fig. 4, the torque detection sensitivity is lowest when a DC biasing magnetic field of +10 to +20 Oe is applied. This phenomenon is considered to result from the fact that the shaft is made of ferromagnetic material and is magnetized prior to the experiment, in consideration of the fact that the experiment was not performed under the condition in which an external disturbance magnetic field is applied to the sensor. In the case where the shaft is not magnetized or the shaft is made of non-magnetic material, the detection sensitivity is lowest at the value of 0 Oe or thereabouts.

Since biasing magnetic field applying source 17 is provided for applying a DC biasing magnetic field to amorphous magnetic metallic ribbons 12 and 13, the torque detection sensitivity can be kept substantially constant by the application of the DC biasing magnetic field having an intensity of a predetermined value or above. Therefore, the shaft torque can be precisely sensed.

Another embodiment of the torque sensor of the present invention will now be described with reference to Figs.5 and 6. Fig. 5 shows detection section 1a of the torque sensor, and Fig. 6 shows signal processing section 2a of the torque sensor. In Figs. 5 and 6, the reference numerals already used in Figs. 1 and 2 denote the same elements as shown in Figs. 1 and 2. A description of these elements may be omitted. The sensor shown in Fig. 5 is not provided with yoke 23, permanent magnet 22, or permanent magnet 24. Instead, in this sensor, coil 50 serving as biasing magnetic field applying source 17a for generating a biasing magnetic field is mounted on the outer peripheral surface of coil bobbin 25a. Signal processing section 2a is provided with DC power source 51 for exciting coil 50.

In this sensor, the same advantages as is obtained in the above embodiment can be obtained, since a desired DC biasing magnetic field can be applied to amorphous magnetic metallic ribbons 12 and 13.

In the above two embodiment, shaft 11 is made of ferromagnetic material and is made hollow. However, shaft 11 may be solid, and may be made of non-magnetic material. The magnetic field generation source of the biasing magnetic field applying source may have one permanent magnet, or three or more permanent magnets. An AC excitation coil may be provided to produce a potential difference between coils 28 and 29 as an output signal. The length of each amorphous magnetic metallic ribbon need not be the same as the circumferential length of the shaft. The bearings may be omitted, if the place of installation does not require them.

Since the torque sensor of the present invention is constituted as described above, the following advantages can be obtained.

The means for applying a DC biasing magnetic field is provided for applying a DC biasing magnetic field to amorphous magnetic metallic members mounted on the shaft. Thus, by setting the intensity of the biasing magnetic field to be applied to a predetermined value or above, a variation in detection sensitivity due to an external magnetic field can be prevented, and the detection sensitivity can be kept constant. Therefore, the torque can always be sensed precisely.

In addition, by using permanent magnets as main components of the means for applying the DC magnetic field, the sensor can be made more reliable, smaller in size, and easier in maintenance.

Claims

1. A torque sensor of a noncontact type for sensing a rotary torque applied to a shaft (11) having an axis, the sensor comprising:
a first magnetic ribbon (12) fixed to the shaft along the circumferential direction of the shaft (11), said ribbon comprising a magnetic material having an induced magnetic anisotropy in a direction of an angle α in respect to the axis of the shaft (11);
means (28, 29) for generating an alternative magnetic field along the shaft (11) and applying the magnetic field to said magnetic ribbon (12); and
means (28, 29) for detecting the magnetic fields passing through said magnetic ribbon to generate an output signal;
characterized by further comprising:
means (19, 21, 22, 23) for generating a constant biasing magnetic field along the shaft (11) and applying the biasing magnetic field to said magnetic ribbon (12).

2. The torque sensor according to claim 1, said sensor characterized by further comprising:
a second magnetic ribbon (13) arranged close to said first magnetic ribbon (12) and fixed to the shaft (11) along the circumferential direction of the shaft (11), said second ribbon (13) comprising a magnetic material having an induced magnetic anisotropy in a direction of an angle $-\alpha$ in respect to the axis of the shaft (11).

3. The torque sensor according to claim 1, characterized in that said magnetic ribbon (12) has a width W along the shaft (11) and a length L along the circumferential direction of the shaft (11), the width W being smaller than the length L.

4. The torque sensor according to claim 1, characterized in that said magnetic ribbon (12) is provided to surround the entire circumference of the shaft (11).

5. The torque sensor according to claim 1, characterized in that said biasing magnetic field generating means (19, 21, 22, 23) includes at least one permanent magnet (23) for generating a biasing magnetic field.

6. The torque sensor according to claim 1, characterized in that said biasing magnetic field generating means (19, 21, 22, 23) includes at least one electromagnet (56) for generating a biasing magnetic field.

7. The torque sensor according to claim 1, characterized in that said means (28, 29) for generating alternating magnetic field includes an electromagnet (28, 29) for generating a high-frequency

alternating magnetic field.

8. The torque sensor according to claim 1, characterized in that said detecting means (28, 29) includes a coil (28, 29) for detecting the magnetic field.

9. The torque sensor according to claim 1, characterized in that said first magnetic ribbon (12) is made of amorphous metal.

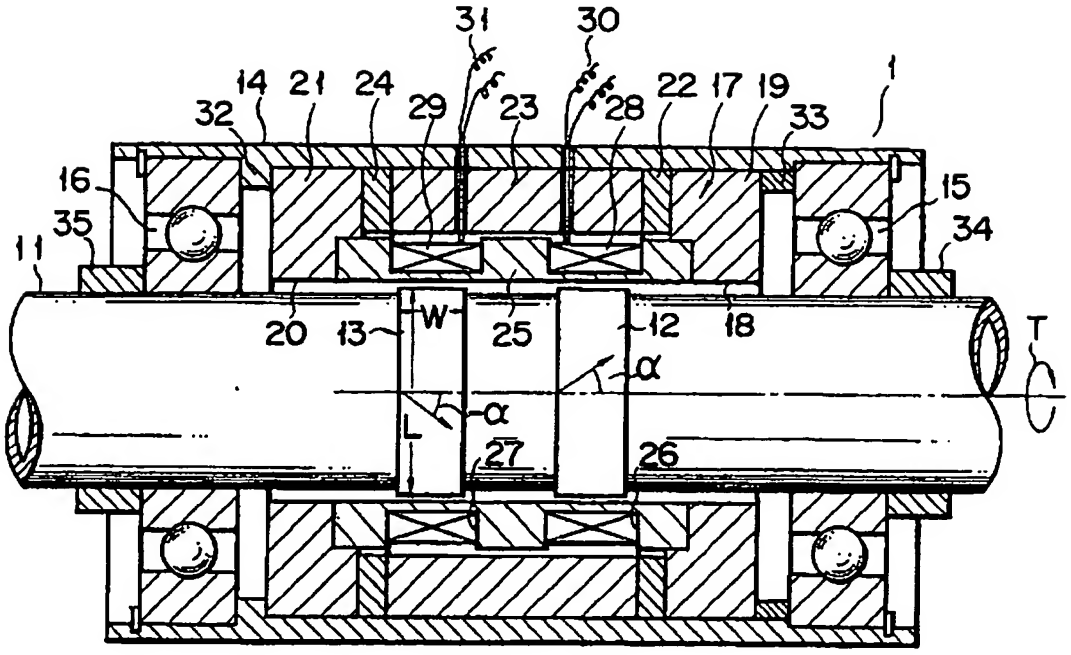
31
30
14
21
24
29
23
28
22
17
19
1
32
33
16
15
35
34
11
20
13
W
25
12
18
T
α
α
L
27
26

FIG. 1

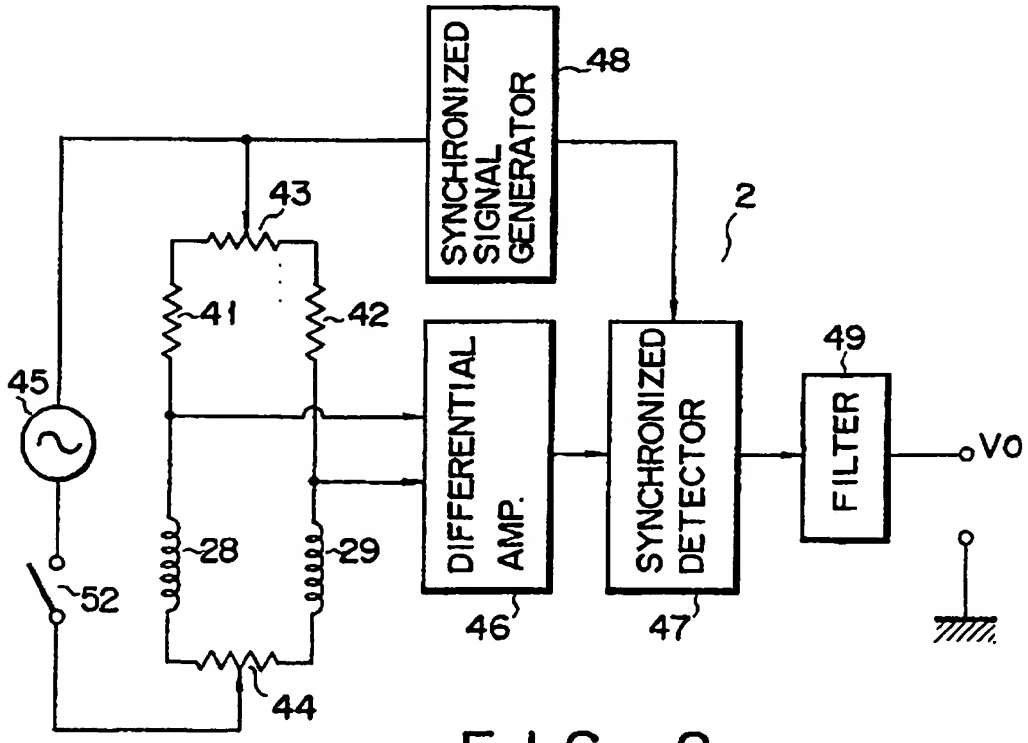
SYNCHRONIZED SIGNAL GENERATOR
48
43
2
41
42
45
DIFFERENTIAL AMP.
SYNCHRONIZED DETECTOR
49
FILTER
Vo
28
29
52
46
47
44

FIG. 2

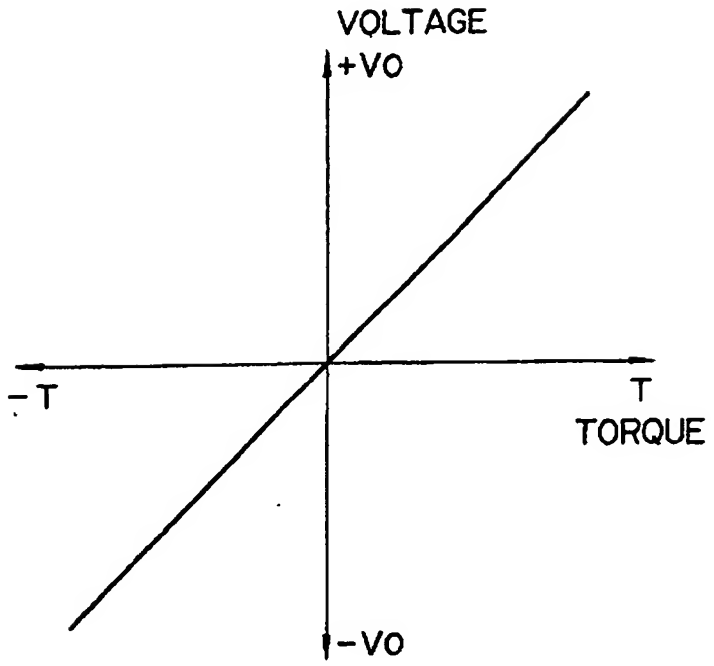
VOLTAGE
+VO
-T
T
TORQUE
-VO

FIG. 3

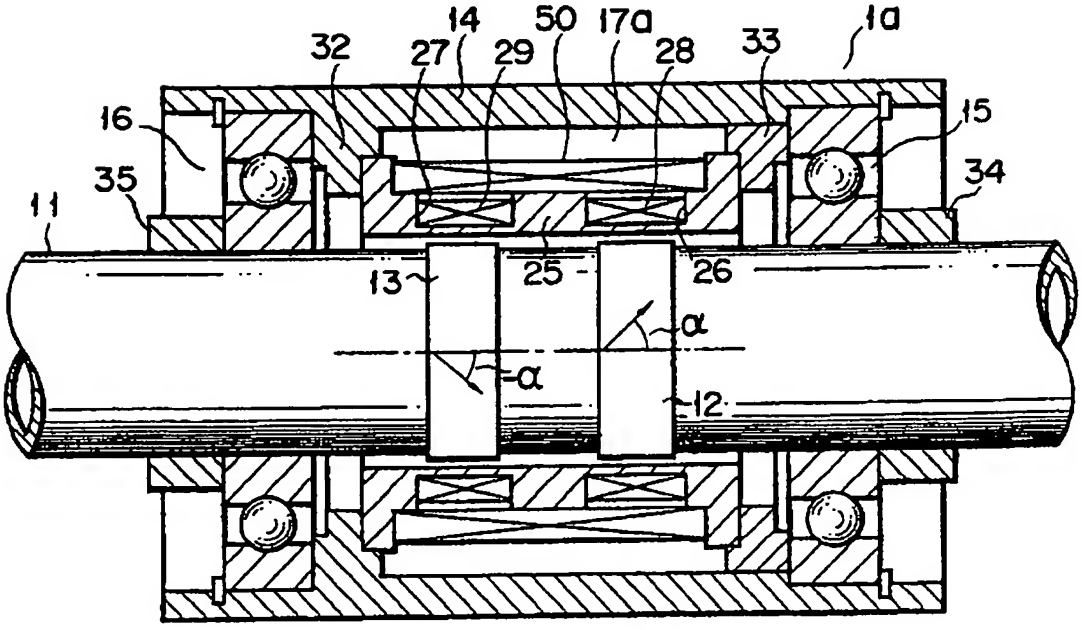
14
50
17a
1a
32
27
29
28
33
16
15
35
34
11
13
25
26
α
-α
12

FIG. 5

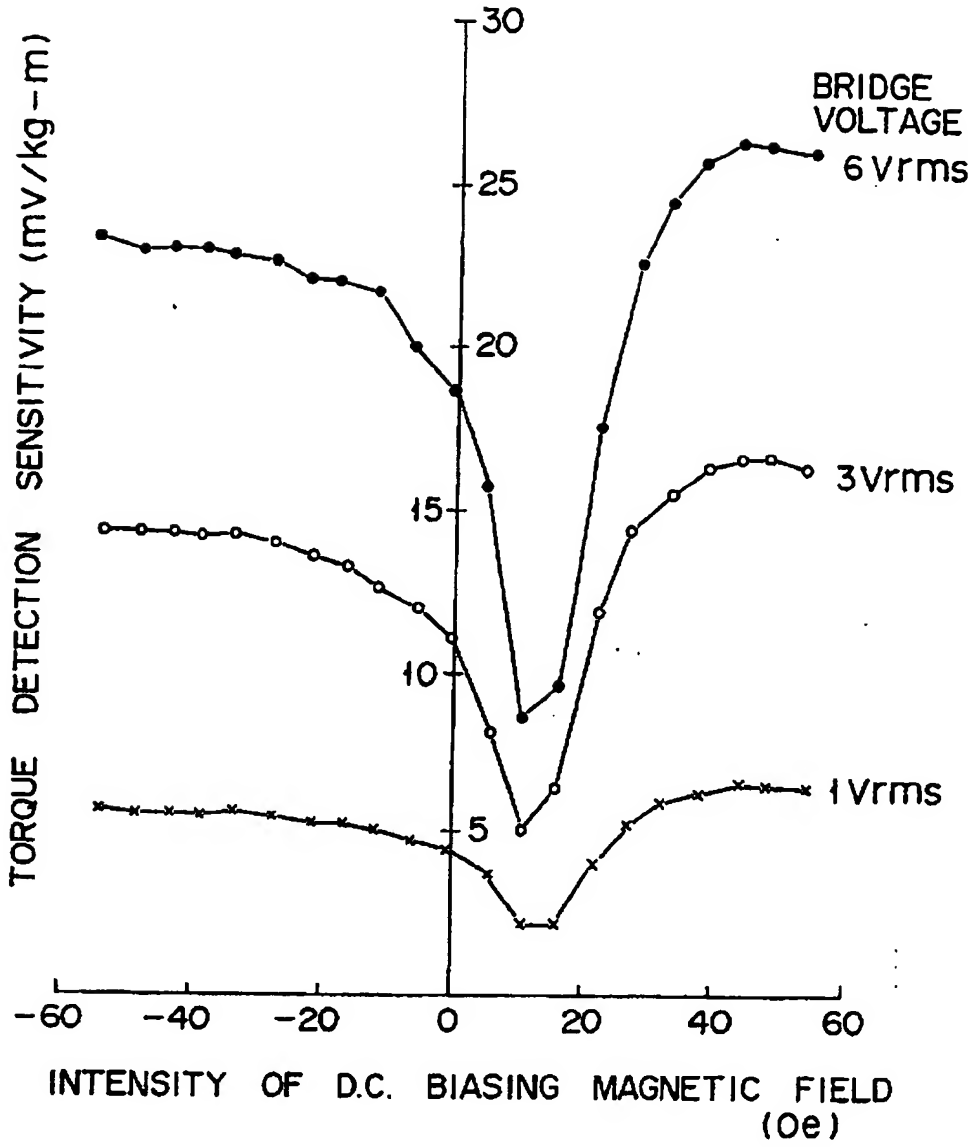
TORQUE DETECTION SENSITIVITY (mV/kg-m)
30
25
20
15
10
5
BRIDGE VOLTAGE
6Vrms
3Vrms
1Vrms
-60
-40
-20
0
20
40
60
INTENSITY OF D.C. BIASING MAGNETIC FIELD (Oe)

FIG. 4

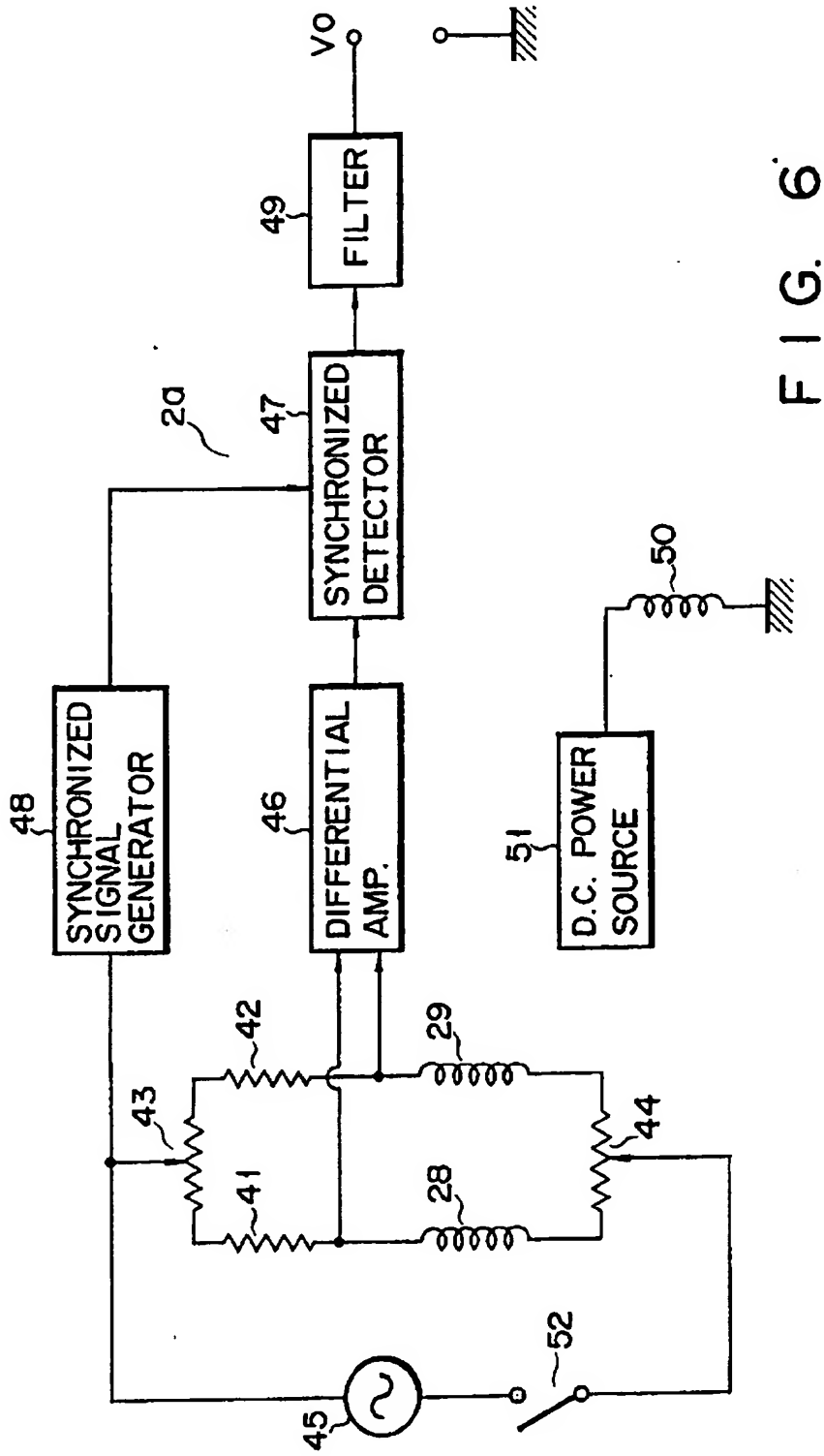
Vo
49
FILTER
47
SYNCHRONIZED DETECTOR
2a
48
SYNCHRONIZED SIGNAL GENERATOR
46
DIFFERENTIAL AMP.
51
D.C. POWER SOURCE
50
42
29
43
44
41
28
52
45

FIG. 6

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(54) Torque sensor.

(57) In a torque sensor of a noncontact type, a pair of amorphous magnetic ribbons (12, 13) are bonded to a shaft (11) to which a rotary torque is applied. A pair of coils (28, 29) are wound around the shaft (11) and an alternative magnetic field is applied from the coils (28, 29) to the magnetic ribbons (12, 13) along the axis of the shaft (11). A permanent magnet (23) and yokes (19, 21) are located around the shaft (11) and a bias magnetic field is also applied from the magnet (23) to the magnetic ribbons (12, 13) through the yokes (19, 21).

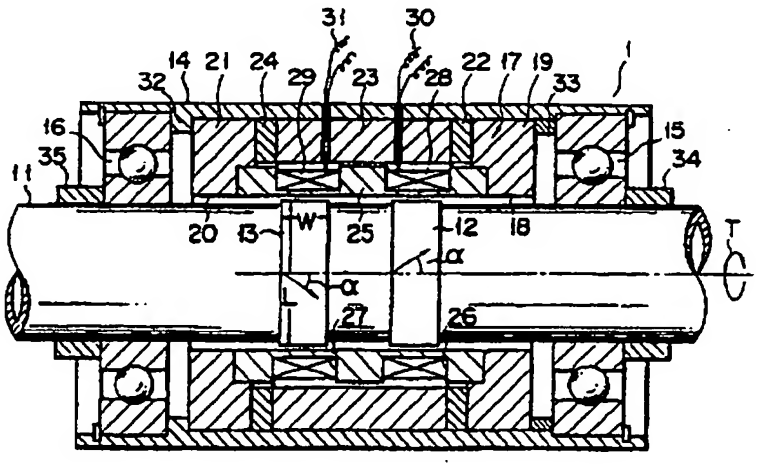

FIG. 1

EP 0 366 217 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 30 0512

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A,D	US-A-4 627 298 (M. SAHASHI et al.) * the whole document *	1,2,4,6	G 01 L 3/10
A,P	EP-A-0 270 122 (MAG DEV INC.) * figures 1,2; column 20, line 40 - column 21, line 4 *	1,2,4,6,7	
A	US-A-4 506 554 (K. BLOMKVIST et al.) * claim 1; figure 2A *	1,2,4-6	
A	IEEE TRANSACTIONS ON MAGNETICS vol. MAG-20, no. 5, part 1, September 1984, pages 951-953, New York, US; I. SASABA et al.: "Torque Transducers with Stress-Sensitive Amorphous Ribbons of Chevron-Pattern" * pages 951-953 *	9	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G 01 L 3/10

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
Berlin	29 October 90	KOEHN G

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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P: intermediate document
T: theory or principle underlying the invention

E: earlier patent document, but published on, or after the filing date
D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

⑲ 日本国特許庁 (JP)　　⑪ 特許出願公開

⑫ 公開特許公報 (A)　　昭58—9034

⑤Int. Cl.³　識別記号　庁内整理番号　⑬公開 昭和58年(1983)1月19日
G 01 L 3/10　7409—2F

発明の数 1
審査請求 未請求

(全 7 頁)

⑭アモルファス磁性薄帯によるトルクセンサ

⑳特　願 昭56—108542
㉒出　願 昭56(1981)7月9日
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明　細　書

1．発明の名称

アモルファス磁性薄帯によるトルクセンサ

2．特許請求の範囲

大きな磁気ひずみ定数を有するアモルファス磁性薄帯を回転軸に巻いて固定し、上記回転軸に加えられたトルクによりアモルファス磁性薄帯の磁気特性が変化することを利用してトルクの非接触検出を可能としたアモルファス磁性薄帯によるトルクセンサ。

3．発明の詳細な説明

電動機、自動車等の回転駆動部において、トルクは制御を行なう場合の最も基本的変量であり、又システムの老朽化の程度を示すパラメータとして、故障診断に利用することもできる。トルクの検出には、非接触方式であることが必要で、正転、逆転及び静止時のトルクが検出でき、精度が良く、信頼性が高いことが要求される。

これまで光や磁気を利用して軸のねじり角からトルクを検出する間接方式や回転軸の磁気ひずみ現象を利用して直接トルクを検出する直接方式が試みられているが、いずれの方式も定着するに至っていない。その原因として間接方式の場合は、トルクをねじり変位に変換するために専用のトーションバーが必要であること、又光の使用は耐環境性の点から問題であることなどがあげられる。これに対し軸の磁気ひずみ現象を利用した直接方式は簡単で信頼性の点で優れているが、元来回転軸は機械的強度のみに注意が払われており、磁気的性質は軸の回転方向に対し一様でなく検出出力に回転ひらが生じ、又出力に回転数依存性のもることが大きい欠点とされていた。

本発明はこの様な欠点を除くため、アモルファス磁性体の優れた機械的特性、材質の均一性、望しい磁気ひずみ特性を利用し直接方式のトルクセンサを提供することを目的としている。すなわち、適当に熱処理を施こした望しい磁気ひずみ特性を有するアモルファス磁性薄帯を回転軸に巻いて固定し、トルクによる軸のひずみ応力がアモルファス磁性薄帯に導入されるようにして、磁気ひずみ

現象によるアモルファス磁性薄帯の磁気特性の変化を外部から非接触に検出することによりトルクを検出する直接方式である。

第1図は本発明の原理図である。第1図(a)はリング状に巻かれたアモルファス磁性薄帯(1)に熱処理によってその長さ方向(2)に対し角αの傾きを持って一様に磁化容易軸Ku(3)を付与したものである。説明を簡単にするためにα＞45°とし、磁気ひずみ定数$\lambda_s>0$と仮定する。第1図(b)はこのアモルファス磁性薄帯(1)を回転軸(4)に巻いて固定したもので、回転軸(4)に第1図(b)の様にトルク(5)が加わるとアモルファス磁性薄帯(1)には第1図(b)の様に±45°の方向にひずみ応力σ(6)が生じ、σの正の方向にも磁気ひずみ効果により一軸磁気異方性が誘導され、結果として合成された磁化容易軸はKu(3)からKu'(7)に変化する。第1図(c)は逆方向のトルク(8)が加わった場合で、この場合合成された磁化容易軸Ku'(9)は第1図(b)のKu'(7)とは逆の関係になる。一般に磁性体の透磁率は、励磁方向に対する磁化容易軸の方向によって変化するから、第1図の様にトルクによって磁化容易軸が変化するようにすれば、アモルファス磁性薄帯の透磁率の変化からトルクの検出が可能となる。

第2図は、コイルの巻き方を表示するための簡略表示法の説明図である。第2図(a)の様にアモルファス磁性薄帯(1)の周囲に巻かれた巻線(10)を第2図(b)の巻線(11)の略記法によって表示する。

第3図は透磁率の変化をインダクタンスの変化として検出する方法である。第3図(a)はアモルファス磁性薄帯(1)の周囲に施こされた検出巻線(12)を用いて、インピーダンス測定器(13)によってインダクタンスを測定する方法である。第3図(b)は高周波電源(14)を用いてインダクタンスの変化を励磁巻線(15)と検出巻線(12)間の相互誘導による誘起電圧の変化として交流電圧計(16)にて検出する方法である。第3図(c)はアモルファス磁性薄帯(1)からわずかに離して配置した磁気ヘッド(17)を用いてインダクタンスの変化をインピーダンス測定器(13)で検出する方法である。上記3つの方法においては、励磁周波数は回転軸(4)が磁化されないように高くすることが必要である。回転軸(4)の回転数に比べ励磁周波数を充分高くすることによって第3図(a)の方法の回転数依存性は除去できる。第3図の3つの方法のいずれかによれば、トルクの大きさの検出とともに、トルクの正転、逆転の区別もトルクが加わっていない時の検出値を基準に選び、トルク印加時の検出値と基準値の大小関係から決定することができる。又磁気ひずみ現象は軸の回転とは無関係であるため静止時、回転時にかゝわりなくトルク検出が可能である。

実際のトルクの検出に際し、高い安定性、良好な精度を得るために、出力を得る方法としては差動的構成にするのが望ましい。以下実施例を用いて説明する。

第1実施例

第4図は第3図(c)の原理を拡張し差動出力が得られるようにしたトルクセンサの基本構成である。2つの磁気ヘッド(18)、(19)を回転軸(4)の軸方向に対し等角度傾けて対称の位置に、アモルファス磁性薄帯(1)からわずかに離して配置し又アモルファス磁性薄帯(1)には磁化容易軸Kuを軸方向からしくは、回転方向に熱処理によって付与する。この2つの磁気ヘッド(18)、(19)を高周波電源(14)でダイオード(20)を介して励磁すると、トルク(5)の印加されていない時は、2つの磁気ヘッドのインダクタンスは対称性から等しくなり励磁電流も等しくなるが、トルクが加わると磁気ひずみ効果によっていずれかの磁気ヘッドのインダクタンスが増加し、他方は減少するため励磁電流間に差が生じる。この励磁電流の差を出力抵抗(21)と平滑用コンデンサ(22)とで直流差動出力Vout (23)として取り出せば、その符号と大きさからトルクの方向と大きさが検出可能となる。

第2実施例

第5図は磁気回路ブリッヂによるトルクセンサの基本構成である。励磁用磁気ヘッド(24)と検出用磁気ヘッド(25)はアモルファス磁性薄帯(1)からわずかに離して、互いに直角になるように設置する。励磁用磁気ヘッド(24)は高周波電源(14)と励磁巻線(26)とによってアモルファス磁性薄帯(1)を

高周波で励磁する。励磁方向は回転軸(4)の軸方向に対し、平行又は垂直とし、磁化容易軸も軸方向に対し平行又は垂直になる様に付与する。トルクが印加されていない時は、対称性からA1B1間磁気抵抗とA1B2間の磁気抵抗は等しくなり、又A2B1間の磁気抵抗とA2B2間の磁気抵抗も同様に等しくなるから、磁気回路ブリッヂはバランスが保たれ励磁用磁気ヘッド(24)による磁束は、検出用磁気ヘッド(25)の中を通らず出力は表われない。これに対し、第5図の様にトルク(5)が印加されると、磁気ひずみ効果により A1B1間及びA2B2間の磁気抵抗の大きさと、A1B2間及びA2B1間の磁気抵抗の大きさは互いに逆に変化するため磁気回路のブリッヂバランスが破れて、検出用磁気ヘッドの中を磁束が通り検出巻線(27)に誘起電圧が生じる。この電圧を同期整流器(28)によって直流として取り出せば、その符号と大きさからトルクの向きと大きさが検出可能となる。

回転軸の強磁性体としての性質を利用する従来の方式に比べ、アモルファス磁性薄帯を用いるため、回転方向の磁気特性の不均一性がなく、又微小な励磁電流で高周波励磁する点が異なっており、本方式の優れている所である。

第3実施例

第6図は、第3図(b)の原理を応用し、同一組成のアモルファス磁性薄帯(1)を2個使用して出力を差動的に取り出す様にしたトルクセンサの基本構成である。検出巻線(12)は誘起電圧を互いに打消す方向に接続する。巻線に付けられた小さな黒丸(29)は巻線の極性を示すものとする。アモルファス磁性薄帯(1)の磁化容易軸Ku(3)はアモルファス磁性薄帯の長さ方向に対し第1図の傾斜角αが各々±α度の角になるよう熱処理によって付与する。トルクが印加されていない時は2つのアモルファス磁性薄帯(1)の透磁率は等しく、従って2つの検出巻線(12)の誘起電圧は互いに等しく逆極性であるから打消し合うため出力は表われない。トルク(5)が印加された場合は、アモルファス磁性薄帯(1)の磁気ひずみ定数 λ_s が正の場合を例にとると、第1図からわかるように磁化容易軸が各々第5図Ku(7)及びKu(9)の方向に変化するため、左側のアモルファス磁性薄帯の透磁率よりも右側の方の透磁率が大きくなり結果として右側の検出巻線の誘起電圧が大きくなる。この誘起電圧の差を同期整流器(28)により直流電圧として出力するものである。トルクの方向が逆の場合も、まったく同じ原理から今度は左側の誘起電圧の方が大きくなり同期整流器(28)の直流出力電圧の符号が反転する。従ってトルクの方向と大きさが検出可能となる。磁気ひずみ定数 $\lambda_s<0$ の場合も上記と同じ原理によって、トルクセンサが構成される。

第4実施例

第7図は、第3図(a)の原理を応用して、同一組成のアモルファス磁性薄帯(1)を2個用いて、トルク検出出力が差動的に出力されるようにしたトルクセンサの基本構成で、回路方式は第4図の第1実施例の場合と同じである。アモルファス磁性薄帯(1)の磁化容易軸Ku(3)は第6図第3実施例の場合と同様に付与する。この場合第7図の様にトルク(5)を印加した時のアモルファス磁性薄帯(1)の透磁率の変化は第6図第3実施例の場合と同様である。このトルク(5)による透磁率変化を励磁電流の変化によって第4図第1実施例と同様の方式で検出することによりトルクの検出が可能となる。

第5実施例

第8図は、第4図第1実施例において、アモルファス磁性薄帯(1)を1個使用し、2個の検出用磁気ヘッド(18)、(19)を回転軸(4)の面にそって斜めに配置した代りに、第3実施例及び第4実施例と同様アモルファス磁性薄帯(1)を2個用いて、検出用磁気ヘッド(30)の取り付けを容易にした トルクセンサである。磁化容易軸Ku(3)は第6図第3実施例及び第7図第4実施例の場合と同様に付与する。回路方式は第4図第1実施例の場合と同じである。従ってトルク(5)による透磁率変化を励磁電流の変化によって検出することでトルクの検出が可能となる。

第6実施例

第9図は、第6図第3実施例において、2個のアモルファス磁性薄帯(1)が同じの磁気ひずみ特性、

すなわち、2つのアモルファス磁性薄帯の磁気ひずみ λ_s が共に正もしくは共に負であったのに対し、異種の磁気ひずみ特性を持つ2個のアモルファス磁性薄帯(1)、(31)を用い、第6図第3実施例と同じ励磁方式によるトルクセンサの基本構成である。磁化容易軸 Ka(3)の方向は、第9図に示している様に同方向に付与する。トルク(5)によるひずみ応力が引き起こすところの磁気ひずみ効果によって誘導される一軸磁気異方性の方向が互いに逆になるためにトルク(5)に比例した差動出力が表われる。この方式によると2種のアモルファス磁性薄帯(1)、(31)の熱処理が同時にできる場合は、磁化容易軸 Ka(3)の方向を正確に合せられる利点を持っている。異種の磁気ひずみ特性を持つアモルファス磁性薄帯を組み合わせて用いる方法は、第4、第5の各実施例においても同様に適用可能である。

以上のようにして、本発明により、トルクを一旦ねじり変位に変換するための専用のトーションバーを必要とせず、静止トルクを始めとして、正転、逆転のトルクを安定かつ精度良く非接触で検出することのできる簡便で工業上適切なトルクセンサが得られる。

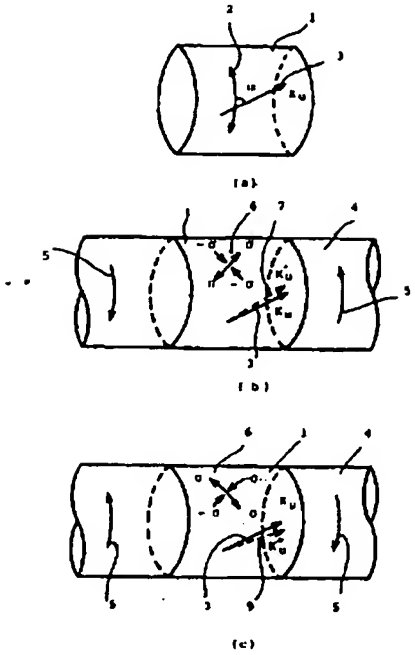
4．図面の簡単な説明

第1図は本発明の原理的説明図、第2図は巻線の時記法に関する説明図、第3図は通過率の検出法に関する説明図、第4図は本発明の第1実施例におけるトルクセンサの原理図、第5図は本発明の第2実施例におけるトルクセンサの原理図、第6図は本発明の第3実施例におけるトルクセンサの原理図、第7図は本発明の第4実施例におけるトルクセンサの原理図、第8図は本発明の第5実施例におけるトルクセンサの原理図、第9図は本発明の第6実施例におけるトルクセンサの原理図を表わす。

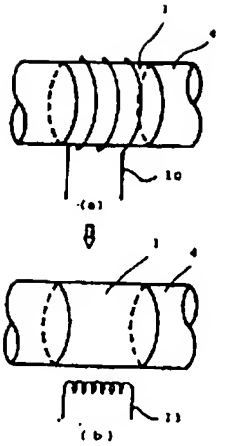
(1) アモルファス磁性薄帯
(2) アモルファス磁性薄帯の長さ方向
(3) 熱処理によって付与された磁化容易軸
(4) 回転軸
(5) トルクの方向
(6) トルクによるひずみ応力の分布
(7) トルク印加によって変化した磁化容易軸
(8) トルクの方向
(9) トルク印加によって変化した磁化容易軸
(10) 巻線
(11) 時記法によって書かれた巻線
(12) 検出巻線
(13) インピーダンス測定器
(14) 高周波電源
(15) 励磁巻線
(16) 交流電圧計
(17) 磁気ヘッド
(18) 磁気ヘッド
(19) 磁気ヘッド
(20) ダイオード
(21) 抵抗
(22) コンデンサ
(23) 出力電圧
(24) 励磁用磁気ヘッド
(25) 検出用磁気ヘッド
(26) 励磁用巻線
(27) 検出巻線
(28) 同期整流器
(29) 巻線の極性を示す記号
(30) 磁気ヘッド
(31) 負の磁気ひずみ定数を有するアモルファス磁性薄帯

特許出願人　原田研介　他1名

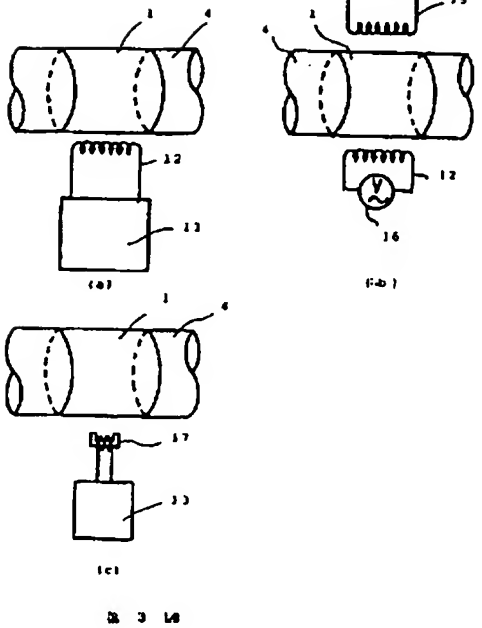
図面の浄書(内容に変更なし)



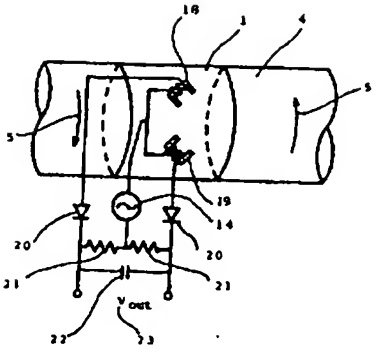
第 1 図



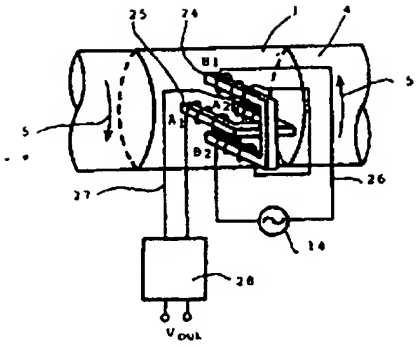
第 2 図



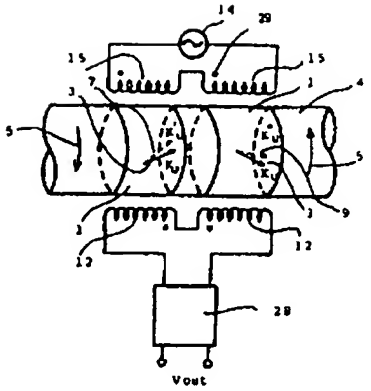
第 3 図



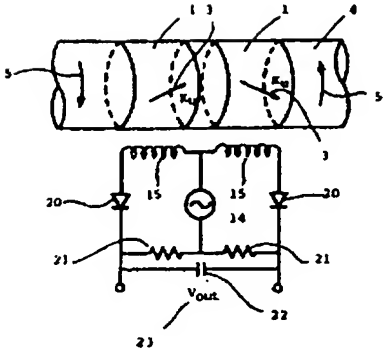
第 4 図



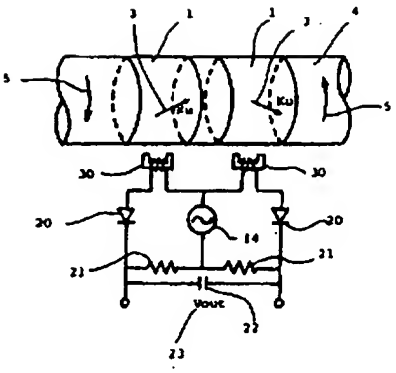
第 5 図



第 6 図



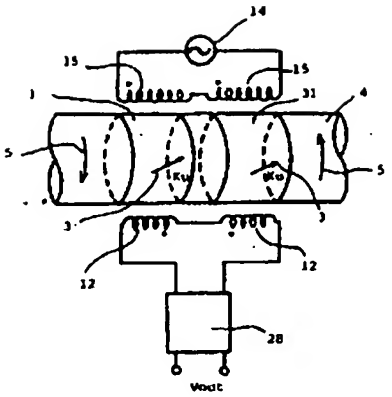
第 7 図



第 8 図

手続補正書（方式）

昭和56年12月23日



第 9 図

特許庁長官　殿

1．事件の表示　昭和56年特許願第108542号

2．発明の名称

アキシャルファン磁性薄膜（ジセイハクマク）によるトルクセンサ

3．補正をする者

事件との関係　特許出願人

住　所　福岡県福岡市中央区薬院2丁目4番6号

氏　名（フリガナ　ハラ　ダ　コク　スケ）　原　田　耕　介　(他1名)

4．補正命令の日付　昭和56年11月　5日

5．補正の対象　図面

6．補正の内容

図面の浄書（内容に変更なし）

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 58-009034
(43)Date of publication of application : 19.01.1983

(51)Int.Cl. G01L 3/10

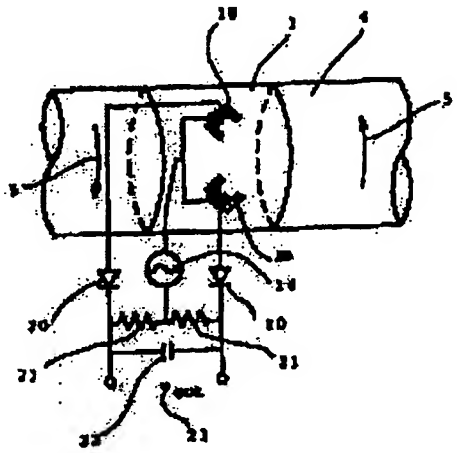
(21)Application number : 56-108542
(22)Date of filing : 09.07.1981

(71)Applicant : HARADA KOSUKE
SASADA ICHIRO
(72)Inventor : HARADA KOSUKE
SASADA ICHIRO

(54) TORQUE SENSOR BY THIN AMORPHOUS MAGNETIC STRIP

(57)Abstract:

PURPOSE: To make the non-contact detection of torque possible by fixing a thin amorphous magnetic strip having a large magnetostriction constant by winding and fixing it to a revolving shaft.



CONSTITUTION: Two magnetic heads 18, 19 are disposed in symmetrical positions with inclination at an equal angle with respect to the axial direction of a revolving shaft 4 spacially slightly from a thin amorphous magnetic strip 1. An easy- to-magnetize axis is applied to the strip 1 in the axial or rotating direction by a heat treatment. When the two heads 18, 19 are excited by a high frequency power source 14 via a diode 20, the inductance of either of the magnetic heads is increased by a magnetostrictive effect and that of the other is decreased on exertion of torque thereupon, thus producing a difference between the excition currents. If the difference in the excitation currents is drawn out as a DC differential output Vout 23, the direction and magnitude of the torque are detected from the code and magnitude thereof.

LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（A）　(11)特許出願公開番号

特開平4－286927

(43)公開日　平成4年(1992)10月12日

(51)Int.Cl.⁵	識別記号	庁内整理番号	Ｆ１	技術表示箇所
Ｇ０１Ｌ　3/10		A　7617－2Ｆ		

審査請求　未請求　請求項の数１（全　5　頁）

(21)出願番号　特願平3－51866

(22)出願日　平成３年(1991)３月18日

(71)出願人　000001052
株式会社クボタ
大阪府大阪市浪速区敷津東一丁目２番47号
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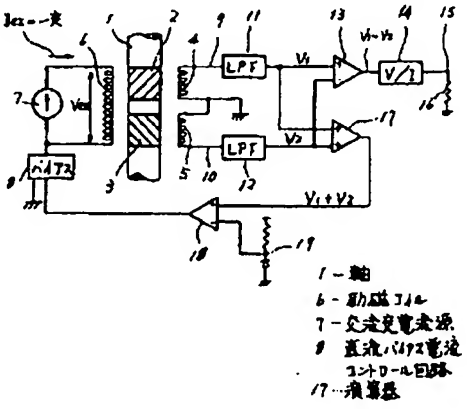
(74)代理人　弁理士　森本　義弘

(54)【発明の名称】　トルク測定装置の感度補償装置

(57)【要約】
【目的】　トルク伝達軸の外周面に形成された磁気異方性部を利用して、検出コイルと励磁コイルとを用いたトルクセンサによりトルクを測定するに際し、センサの感度の温度補償を図る。
【構成】　励磁コイル６への交流定電流源７に、直流バイアス電流コントロール回路８が付加される。一対の検出コイル４，５からの検出電圧の和V_1+V_2が演算器17から出力され、これによりセンサ部の温度が表される。この和V_1+V_2の値にもとづきコントロール回路８に信号が送られ、直流バイアス電流が増減される。
【効果】　直流バイアス電流の変化にともなってトルク検出出力を変化させることができ、検出感度を温度補償できる。



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【特許請求の範囲】

【請求項1】　トルク伝達軸の外周面に磁気異方性部を形成し、この磁気異方性部に対応して励磁コイルと検出コイルとを設け、前記トルク伝達軸に印加されるトルクの大小に応じた信号を前記検出コイルから出力して前記トルクの大きさを測定するようにした磁歪式のトルクセンサにおいて、前記励磁コイルに交流電流を供給する手段と、前記励磁コイルの励磁電流に直流成分をバイアスさせる手段と、センサ部の温度を検出する手段と、温度検出信号にもとづいて直流バイアス電流を制御する手段と、を有することを特徴とするトルク測定装置の感度補償装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、トルク測定装置の感度補償装置に関する。

【0002】

【従来の技術】公知のトルク測定装置として、トルク伝達軸の外周に一対の磁気異方性部を形成し、この軸にトルクが印加されたときの各磁気異方性部の透磁率の変化を、これら磁気異方性部の近傍に配置された一対の検出コイルで検出し、両検出信号の差から、軸に作用するトルクの大きさを電気信号に変換するようにしたものであって、前記検出コイルを励磁するための励磁コイルを有したものが、たとえば特開平1－173843号公報において提案されている。

【0003】この種のトルク測定装置では、磁気異方性部が形成された軸部分や検出コイルや励磁コイルなどを備えたトルク検出部に温度変化が生じると、その磁気特性や電気特性が変化し、励磁コイルのインピーダンスが変化してその励磁電流が変化する。この結果トルク検出感度が大きく変化して、その検出精度に変動が生じる。このため、産業機械、モータ、エンジン、自動車など、運転時に比較的高温になる装置のトルクを測定する際に問題となる。

【0004】そこで特開平1－173843号公報では、励磁電流の変化と温度変化とに相関があることに着目し、検出コイルの出力信号の電圧の和、すなわち両信号の平均値の2倍の値を一定にする定電圧制御により励磁電流を制御して、このような事態の発生を防止している。

【0005】

【発明が解決しようとする課題】しかし、このような公知のものでは、両検出信号の差の増幅率を一定としているため、両検出信号の和を一定とする励磁電流の制御下では、センサが特に高温になるとトルク検出信号が大きめに出力され、その感度が変動することになってトルク測定値に誤差が生じるという問題点がある。

【0006】そこで本発明は、低温下や特に高温下でのトルクセンサの感度を補償して、このような測定誤差が生じないようにすることを目的とする。

2

【0007】

【課題を解決するための手段】上記目的を達成するため本発明は、トルク伝達軸の外周面に磁気異方性部を形成し、この磁気異方性部に対応して励磁コイルと検出コイルとを設け、前記トルク伝達軸に印加されるトルクの大小に応じた信号を前記検出コイルから出力して前記トルクの大きさを測定するようにした磁歪式のトルクセンサにおいて、前記励磁コイルに交流電流を供給する手段と、前記励磁コイルの励磁電流に直流成分をバイアスさせる手段と、センサ部の温度を検出する手段と、温度検出信号にもとづいて直流バイアス電流を制御する手段と、を有する構成としたものである。

【0008】

【作用】このような構成において、センサの感度は、たとえばセンサ部の温度が上昇すると大きくなり、反対に直流バイアス電流の増大にともなって小さくなる。したがって、温度検出手段の出力にもとづき、センサ部の温度が上昇したときには、直流バイアス電流を増加させることで感度を低下させて感度補償を達成することが可能となる。

【0009】なお、2次側である検出コイルの出力波形は、1次側である励磁コイルの波形の微分波形にて構成されるため、励磁側で直流電流を増減しても、トルク測定値自体には何ら影響はない。

【0010】

【実施例】図1は本発明の第1実施例を示す。ここで1はトルク伝達用の軸であり、軟磁性および磁歪性を有する材料にて形成されている。軸1の外周には、この軸1の軸心の方向と±約45度の角度をなして互いに反対方向に傾斜する磁気異方性部2，3が、多数の溝などによって形成されている。磁気異方性部2，3の周囲には、各磁気異方性部2，3に対応した検出コイル4，5と、これら検出コイル4，5を励磁するための励磁コイル6とが設けられている。励磁コイル6は交流の定電流源7に接続されている。8は直流バイアス電流コントロール回路で、励磁コイル6の励磁電流に直流のバイアス成分を付加可能である。Vex は交流励磁電圧、Iex は交流励磁電流を示す。

【0011】各検出コイル4，5からの出力ライン9，10は、整流フィルタ11，12の入力側にそれぞれ接続され、またこれら整流フィルタ11，12の出力側は、減算のための演算器13の入力側に接続されている。演算器13の出力側は、V／I変換器14を介して、出力端子15に導かれている。16は、負荷抵抗である。

【0012】整流フィルタ11，12の出力側は、加算のための演算器17の入力側にも接続されている。演算器17の出力側は比較器18の一方の入力側に接続され、この比較器18の他方の入力側には定電圧発生回路19が接続されている。比較器18の出力側は直流バイアス電流コントロール回路8に接続され、このコントロール回路8を制御し

て直流バイアス電流を増減可能とされている。

【００１３】このような構成によれば、軸１に作用するトルクにもとづく各磁気異方性部２，３での透磁率の変化が、検出コイル４，５にて検出される。このとき、磁気異方性部２，３は互いに反対方向に傾斜しているため、一方の磁気異方性部に引張力が働くと、他方には圧縮力が働く。このため、たとえば一方の検出コイル４の検出電圧V_1がトルクの増加にしたがって増加すると、他方の検出コイル５の検出電圧V_2はそれにともなって減少する。そこで、演算器13により両検出電圧V_1，V_2の差V_1-V_2を求めると、図２に示すようにトルクの変化に対応する信号が出力端子15に現れる。tは所定の大きさのトルク、v_1はトルクtに対応した出力である。

【００１４】演算器17の出力側に現れる検出電圧の和V_1+V_2の値は、比較器18において定電圧発生回路19からの基準電圧と比較される。この和V_1+V_2の値は、図３に示すように、センサ部の温度が上昇すると反対に減少する傾向にあるため、このセンサ部の温度値を表す信号となる。たとえば、図示のように、センサ部の温度が20℃のときに　v_{20}という値をとり、またセンサ部の温度が120℃のときにはv_{120}（v_{20}　＞　v_{120}）という値をとる。

【００１５】センサの感度すなわち単位トルクあたりの出力信号は、図４に示すように、温度の上昇にともなって増大する。たとえば、図示のように、センサ部の温度が20℃のときにS_{20}という値をとり、またセンサ部の温度が120℃のときにはS_{120}（S_{20}＜S_{120}）という値をとる。

【００１６】一方、図５に示すように、励磁コイル６に供給する直流バイアス電流を増大させると、それにともなってセンサ感度は低下する傾向にある。この図５において、バイアス電流I_0，I_1に対応する感度は、それぞれS_0，S_1である。

【００１７】いま、励磁回路にバイアス電流を全く付加しなければ、図６に示す高温時には、図４で説明したようにセンサ感度が増大し、トルクtが加わったときに、正しい出力v_1よりも大きな出力v_1'が現れ、測定誤差が生じるので、これを補償する。ここで、常温時（20℃）には、励磁回路にはバイアス電流は付加されず、その直流バイアス電流値は０mAである。適切なバイアス電流を求めるために比S_0/S_1を考えると、

$$S_t/S_1 = v_1/v_1' \quad (1)$$

となる。ところが、

$$S_{120} = v_1'/t \quad (2)$$

$$S_{20} = v_1/t \quad (3)$$

であるから、(2)，(3)式を(1)式に代入することで、結局、

$$S_{120} \times S_0/S_1 = S_{20} \quad (4)$$

となる。この比S_0/S_1が、バイアス回路による補正係数となる。

【００１８】すなわち、上述のごとく、センサの感度は、図４に示すようにセンサ部の温度が上昇すると大きくなり、反対に図５に示すように直流バイアス電流の増大にともなって小さくなる。一方、検出電圧の和V_1+V_2の値は、図３に示すようにセンサ部の温度が上昇すると減少する。そこで、検出電圧の和V_1+V_2の値からセンサ部の温度を検出し、それにもとづき直流バイアス電流を制御することで、具体的には、検出電圧の和V_1+V_2の値が減少したときにバイアス電流を増加させることで、高温時のセンサ感度を補償することができる。

【００１９】なお、２次側である検出コイル４，５の出力波形は、１次側である励磁コイル６の波形の積分波形にて構成されるため、励磁側で直流電流を増減しても、トルク測定値自体には何ら影響はない。

【００２０】このようにセンサ感度を温度補償することで、図６に示すように、センサ部の温度変化にともなう感度誤差を軽減して、常温時とほぼ同等の検出出力特性を得ることができ、広い温度範囲でより高精度なトルク測定が可能なトルクセンサを構成することができる。

【００２１】図７は、本発明の第２実施例を示す。ここでは、演算器と整流フィルタとによって励磁電圧検出回路21を構成し、また励磁コイル６の励磁用電源として、図１の場合と同様の交流の定電流源７を利用している。図８に示すように、定電流源７を用いたときの励磁電圧V_{ex}はセンサ部の温度の上昇に比例して増大するため、検出回路21の検出信号がセンサ部の温度を表す信号となる。そこで、この励磁電圧検出回路21の出力を図１の場合と同様に比較器18に入力し、それに応じてバイアス電流を制御することで、センサ感度を温度補償することができる。

【００２２】図９は、本発明の第３実施例を示す。ここでは、励磁回路に検出抵抗22を設け、演算器と整流フィルタとによって構成された励磁電流検出回路23をこの検出抵抗22に接続することで、励磁電流I_{ex}を検出するようにしている。励磁コイル６の励磁用電源には、交流の定電圧源24を用いている。図10に示すように、定電圧源24を用いたときの励磁電流I_{ex}はセンサ部の温度の上昇に反比例して減少するため、検出回路23の検出信号がセンサ部の温度を表す信号となる。そこで、図１や図７の場合と同様にバイアス電流を制御することで、センサ感度を温度補償することができる。

【００２３】図11は、本発明の第４実施例を示す。ここでは、図９と同様の検出抵抗22および励磁電流検出回路23を用いて、バイアス電流を制御している。励磁コイル６の励磁用電源には、一般的な交流電源29を用いている。そして、この交流電源29に、前述の特開平１－173843号公報に開示されたのと同様の、検出コイルの出力信号の電圧の和を一定にするようにフィードバック制御する定電圧制御回路25を組み合わせている。この定電圧制御回路25は、検出電圧の和V_1+V_2を演算する演算器17

5

と、その演算結果を定電圧発生回路26からの基準電圧と比較する比較器27と、この比較器27からの信号にもとづいて励磁電圧Vex を制御するように励磁回路に組み込まれたオートゲインコントローラ28とを有している。

【0024】このような構成であると、バイアス電流を制御することによる感度補償の効果と、検出コイルの出力信号の電圧の和が一定になるように制御することによる感度補償の効果との相乗効果を得ることができ、きわめて高精度の感度補償を可能とすることができる。

【0025】

【発明の効果】以上述べたように本発明によると、励磁コイルに交流電流を供給する手段と、励磁コイルの励磁電流に直流成分をバイアスさせる手段と、センサ部の温度を検出する手段と、温度検出信号にもとづいて直流バイアス電流を制御する手段とを有する構成としたため、直流バイアス電流の制御によってセンサの感度を補償することができ、このためセンサ部の温度変化にもとづく感度誤差を軽減することができ、広い温度範囲でより高精度にトルクを測定することが可能となる。

【図面の簡単な説明】

【図1】本発明の第1実施例のトルク測定装置の感度補償装置の回路図である。

【図2】同トルク測定装置の常温時の出力特性を示す図である。

【図3】同トルク測定装置における出力電圧の和の温度特性を示す図である。

6

【図4】同トルク測定装置の感度の温度特性を示す図である。

【図5】同トルク測定装置の感度補償装置における直流バイアス電流と測定感度との関係を示す図である。

【図6】同トルク測定装置の高温時の出力特性を示す図である。

【図7】本発明の第2実施例のトルク測定装置の感度補償装置の回路図である。

【図8】同トルク測定装置における励磁電圧の温度特性を示す図である。

【図9】本発明の第3実施例のトルク測定装置の感度補償装置の回路図である。

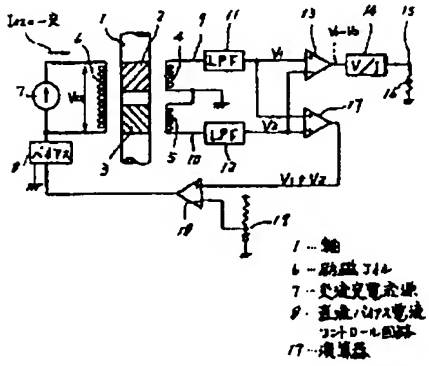
【図10】同トルク測定装置における励磁電流の温度特性を示す図である。

【図11】本発明の第4実施例のトルク測定装置の感度補償装置の回路図である。

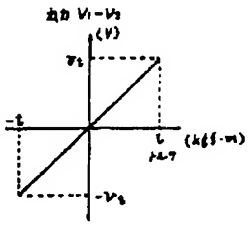
【符号の説明】

1　軸
6　励磁コイル
7　交流定電流源
8　直流バイアス電流コントロール回路
17　演算器
21　励磁電圧検出回路
23　励磁電流検出回路
24　交流定電圧源
25　定電圧制御回路

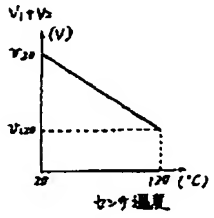
【図1】



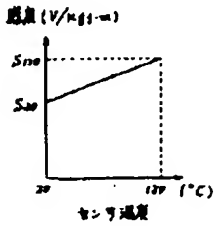
【図2】



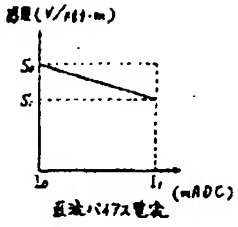
【図3】



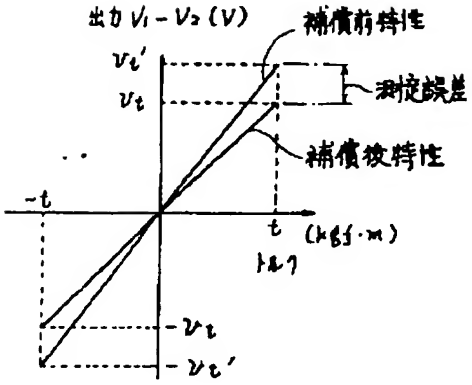
【図4】



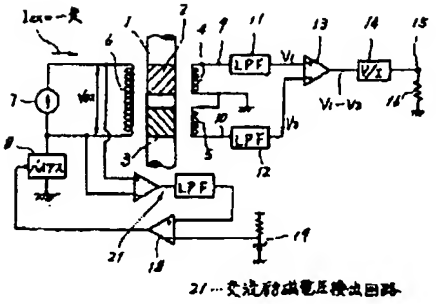
【図5】



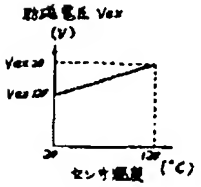
【図6】



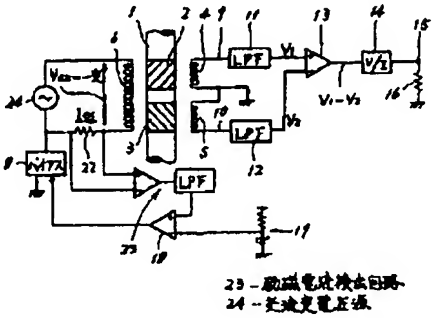
【図7】



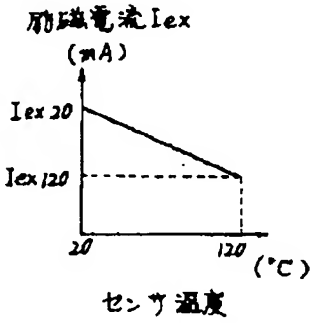
【図8】



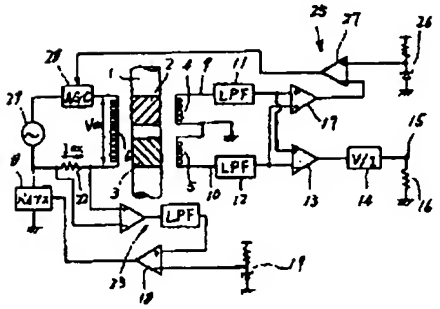
【図9】



【図10】



【図11】



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(71)Applicant : KUBOTA CORP

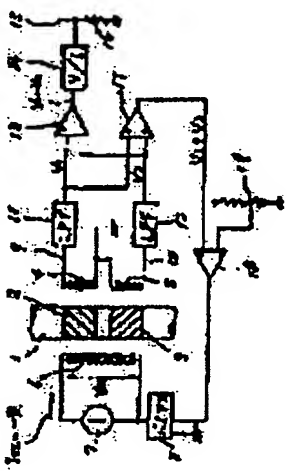
(72)Inventor : HANAZAWA AKIYOSHI

(54) COMPENSATING APPARATUS FOR SENSITIVITY OF TORQUE MEASURING DEVICE

(57)Abstract:

PURPOSE: To temperature-compensate sensitivity of a sensor when a magnetically anisotropic part formed on an outer periphery of a torque transmission shaft is utilized and torque is measured by means of a torque sensor using a detection coil and an excitation coil.

CONSTITUTION: A dc bias current control circuit 8 is added to an ac constant current source 7 to an excitation coil 6. A sum V1+V2 of detected voltages from a pair of detection coils 4,5 is output from an arithmetic device 17, whereby temperature of a sensor part is represented. A signal is sent to the control circuit 8 based on the value of this sum V1+V2 so that dc bias current is increased/decreased. A torque detection output can be varied according to a change in dc bias current, thereby temperature-compensating detection sensitivity.



LEGAL STATUS

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the examiner's decision of rejection or
application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

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decision of rejection]

[Date of requesting appeal against examiner's
decision of rejection]

[Date of extinction of right]

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13. Jan. 2004

WV: ...../ LF: .....

Date of mailing (day/month/year) 29 December 2003 (29.12.03)	
Applicant's or agent's file reference 52016 WO	**IMPORTANT NOTIFICATION**
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International publication date (day/month/year) Not yet published	Priority date (day/month/year) 25 September 2002 (25.09.02)
Applicant FAST TECHNOLOGY AG. et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An asterisk(*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

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Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
25 Sept 2002 (25.09.02)	0222296.6	GB	12 Dece 2003 (12.12.03)

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PATENT COOPERATION TREATY

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Date of mailing *(day/month/year)*	02.12.2004
Applicant's or agent's file reference 52016 WO	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP 03/10634	24.09.2003	25.09.2002

Applicant
FAST TECHNOLOGY AG. et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international preliminary examining authority:	Authorized Officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Püschel, S Tel. +49 89 2399-5812

Form PCT/IPEA/416 (January 2004)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 52016 WO	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/EP 03/10634	International filing date *(day/month/year)* 24.09.2003	Priority date *(day/month/year)* 25.09.2002
International Patent Classification (IPC) or both national classification and IPC G01L3/10		
Applicant FAST TECHNOLOGY AG. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☐ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29.03.2004	02.12.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Coda, R Telephone No. +49 89 2399-2802

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP 03/10634

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-16 as originally filed

Claims, Numbers

1-14 as originally filed

Drawings, Sheets

1/7-7/7 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application,

   ☒ claims Nos. 1-14

   because:

   ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (specify):

   ☒ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. 1-14 are so unclear that no meaningful opinion could be formed *(specify)*:

   see separate sheet

   ☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

   ☐ no international search report has been established for the said claims Nos.

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the Standard.

   ☐ the computer readable form has not been furnished or does not comply with the Standard.

Re Item III

Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. Although claims 1, 7, 11 and 13 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection. Hence, claims 1, 7, 11 and 13 do not meet the requirements of Article 6 PCT.

2. In order to overcome this objection, it would appear appropriate to file an amended set of claims defining the relevant subject-matter in terms of a single independent apparatus claim followed by dependent claims covering features which are merely optional (Rule 6.4 PCT).

3. In view of the above objection it is not at present practicable to carry out a full examination of the application. A preliminary examination of the independent claim 1, which is considered to be the broadest independent claim of the application, has been however carried out.
The subject-matter of claim 1 is not new (Art. 33(2) PCT). In fact, document D1 (US4882936) discloses a torque transducer (see column 1, lines 11 to 14) having: a shaft subject to torque about a longitudinal axis, a transducer element integral with the shaft and remanently magnetised to emanate a component of magnetic field dependent on the torque applied to the shaft (see column 8, lines 1 to 8; figure 1(2, 6, 8)), a sensor coil disposed about the shaft to generate a signal dependent of the applied torque (see column 13, lines 39 to 48, 52 to 59; column 4, lines 1 to 9; figure 1 (20, 24)), a load connected to the coil to enable a current to circulate in the coil (see column 14, lines 18 to 40) and a receiver responsive to the field emanated by the coil to generate a torque dependent signal (see column 13, lines 56 to 59).
In particular, it is noted that at column 26, lines 3 to 14 it is disclosed the possibility of having a receiver which is remote from the coil.

EXHIBIT 6

BECKER • KURIG • STRAUS

MÜNCHEN – BERLIN

119500 Rec Blank 9/1/

Patentanwälte Becker Kurig Straus • Bavariastr. 7 • D-80336 München

Blank Rome LLP
Attn.: Mr. Brian Higgins
600 New Hampshire Avenue, N. W.
20037 Washington, DC
USA

BLANK ROME LLP
SEP 01 2005
RECEIVED
COUNSELORS AT LAW

Via Fax and DHL

Galileo®

Patent- und Rechtsanwälte
European Patent Attorneys
European Trademark Attorneys

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Dr. Roman Vuille[1], Dipl.-Chem.
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August 30, 2005
(AS/SL)

Assignments and Declarations regarding US 10/482,002, US 10/498,058, US 10/480,597, US 10/477,180, US 10/485,960, PCT/EP2004/00044 and PCT/EP03/09349 forwarded to Lutz May

Applicant / Owner:	METHODE ELECTRONICS, INC.
Title:	Methode ./. May
Our Ref.:	51856 KLAGE

Dear Brian,

The Assignments and Declarations together with all documents forwarded to us via your e-mail dated August 23, 2005 were sent to Lutz May on August 24, 2005.

For execution of the Assignment and Declaration regarding US 10/482,002 and returning the documents to us we set him a deadline until today. As expected, he did not return the executed formal papers.

For execution and returning the Assignments and Declarations regarding US 10/498,058, US 10/480,597, US 10/477,180, US 10/485,960, PCT/EP2004/00044 and PCT/EP03/09349 we set Lutz May a deadline until September 7, 2005.

We enclose copies of the letters sent to Lutz May on August24, 2005 together with the official receipt from the courier service, showing that the documents have been delivered and received by Lutz May.

Very truly yours,
Becker · Kurig · Straus

Dr. Alexander Straus

Encl.: C/letters to Lutz May dated Aug. 24, 2005
Receipt of courier service

PREVIOUSLY DOCKETED
119508.0236
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EXHIBIT 7

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. National Stage Appln. of)
)
Lutz Axel MAY)
)
)
)

MEMORANDUM OF LAW PREPARED PURSUANT TO M.P.E.P. 409.03(f)

Commissioner for Patents
U.S. Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

A. Background

1. I, Klaus Gennen, a citizen of Germany, am a Partner in the German law firm of *Legerlotz Laschet Rechtsanwälte* (LLR), which is a firm established according to the German Civil Code. As a German *rechtsanwälte*, or legal attorney, I am licensed to practice law in Germany. I have experience in the field of German Industrial Property Law, including experience with employee invention law and, in particular, the July 25, 1957, German Act on Employees' Inventions (*Arbeitnehmererfindungsgesetz*, or "ArbEG"), as amended, which is relevant to this memorandum of law.

2. This memorandum of law has been prepared to address the question of whether Magna-Lastic Devices, Inc., or its sister company, Abas, Inc., both of which are wholly-owned subsidiaries of Methode Electronics, Inc., has a proprietary interest in the patent properties that are identified in Exhibit A attached hereto. This memorandum of law, in my opinion, demonstrates that the questions should be answered in the affirmative.

3. I have been informed by my colleagues in the United States, whom are registered United States patent attorneys, that the U.S. Patent & Trademark Office (USPTO) Manual of Patent Examining Procedures (M.P.E.P.), § 409.03(f), states that a proprietary interest in the patent applications recited in Exhibit A (or based on the applications in Exhibit A) may be demonstrated by a legal memorandum to the effect that a court of competent jurisdiction would, by the weight of authority in that jurisdiction, award title of the inventions

that are the subject of or based on the patent applications in Exhibit A to Magna-Lastic Devices, Inc. or Abas, Inc. I have also been informed by those colleagues that according to M.P.E.P. § 409.03(f), the facts in support of any conclusion that a court would award title to Magna-Lastic Devices, Inc., or Abas, Inc., should be made of record by way of an affidavit or declaration of a person or persons having firsthand knowledge of same. I have also been informed that the legal memorandum should be prepared and signed by an attorney at law familiar with the law of the jurisdiction involved and that a copy (in the English language) of a statute (if other than a United States statute) or a court decision (if other than a reported decision of a U.S. federal court or a decision reported in the United States Patents Quarterly) relied on to demonstrate a proprietary interest should also be made of record.

4. In this case, the court of competent jurisdiction is the German courts, and in particular, the Patent Dispute Division of the *Landgericht Müchen I* Court (i.e., Munich Regional Court I). That court is a court of competent jurisdiction because the inventions that are the subject of or based on the patent applications in Exhibit A were made by a German citizen in Germany working, at the time, for a German corporation.

5. A copy of the relevant sections of the aforementioned ArbEG statute (in English) is being provided in Exhibit B attached hereto.

6. As stated in the Declaration of Alexander Strauss, which I was told was previously submitted to the USPTO in connection with one or more of the U.S. patent applications identified in Exhibit A, repeated attempts were made to obtain Mr. May's signature on assignment documents to clear title in connection with the properties in Exhibit A and, in particular, to obtain Mr. May's signature on assignments and other forms that had not been executed by him before the Fast Technology bankruptcy, or that are now needed in connection with new patent applications that have been filed by Abas, Inc., in the USPTO and elsewhere based on the properties in Exhibit A.

7. After repeated failures on the part of Mr. May to execute the application papers and assignment documents, he was sued by Abas, Inc., on January 17, 2005, in the Patent Dispute Division of the Munich Regional Court I. As of the date of this memorandum, the lawsuit against Mr. May was fully briefed, argued before the court, and is still pending. The relief sought under the lawsuit is an award of ownership of the properties in Exhibit A in the name of Magna-Lastic Devices, Inc., or Abas, Inc.

B. Statement of Pertinent Facts

8. Fast Technology AG was a German corporation created and governed under the laws of Germany.

9. Fast Technology AG was the successor-in-interest to Fast Technology GmbH under German law (Fast Technology GmbH and Fast Technology AG are hereinafter referred to as "Fast Technology").

10. I was told that between 1999 and 2003, Lutz Axel May was initially the managing director and then the authorized signatory of FAST Technology GmbH, as well as a member of the board of FAST Technology.

11. I was told that between 1999 and 2003, Mr. May was involved in the inventions identified in Exhibit A within the scope of his work as an employee of Fast Technology.

12. I was told that between 1999 and 2003, Mr. May was involved in the inventions identified in Exhibit A within the scope of his work as a managing director of Fast Technology.

13. I was told that between 1999 and 2003, Mr. May was involved in the inventions identified in Exhibit A within the scope of his work as an authorized signatory of Fast Technology.

14. I was told that between 1999 and 2003, Mr. May was involved in the inventions identified in Exhibit A within the scope of his work as a member of Fast Technology.

15. On information and belief, Mr. May is the named inventor or named joint inventor on the patent applications listed in Exhibit A.

16. During his employment with Fast Technology, as I was told, Mr. May was solely responsible for patent matters at Fast Technology, including patent applications to be executed in the names of Fast Technology.

17. I was told that Mr. May was solely responsible for making decisions regarding patent matters, both during his time as an employee of the company and also during his activity as managing director and member of the board of Fast Technology.

18. Thus, although Mr. May's title and degrees of responsibility changed within Fast Technology over time, he always maintained his role as the manager of patent matters.

19. I was told that during the same time period, Fast Technology was aware of the patent applications identified in Exhibit A.

20. I was told that all of the costs associated with submitting and prosecuting the applications identified in Exhibit A were borne solely by Fast Technology and not by Mr. May.

21. I was told that Mr. May had knowledge of this cost-bearing arrangement, and, in fact, it came about at his instigation.

22. Fast Technology became insolvent at the beginning of 2003.

23. Insolvency proceedings concerning the assets of Fast Technology were instituted August 1, 2003, in the AG Municipal Court, Munich 1501 IN 1724/03. Dr. Hans von Gleichenstein, from the Law Office Gleichenstein & Breitling, Rottmannstrasse 11A, 80333 München, was appointed as the insolvency administrator.

24. On August 22, 2003, Magna-Lastic Devices, Inc., acquired the intellectual property rights of Fast Technology as shown in the August 22, 2003, Sales and Transfer Agreement executed by Dr. von Gleichenstein and Magna-Lastic Devices, Inc., which is included in Exhibit C attached hereto.

25. On information and belief, the properties identified in the Sales and Transfer Agreement were subsequently transferred from Magna-Lastic Devices, Inc. to Abas, Inc.

26. On information and belief, after August 22, 2003, Magna-Lastic Devices, Inc., learned that some of the applications identified in Exhibit A had not been formally assigned by Mr. May to Fast Technology, by way of a duly executed written assignment, when Magna-Lastic Devices, Inc., acquired the intellectual property rights on August 22, 2003.

27. On information and belief, it was also learned by Magna-Lastic Devices, Inc., that Mr. May had not executed Declarations for Patent Application and Power of Attorney forms for some of the U.S. applications identified in Exhibit A (as well as for newer U.S. applications that are based on the properties identified in Exhibit A that were filed in the USPTO after the August 22, 2003, acquisition).

C. Analysis: Demonstration of Proprietary Interest

28. As a managing director and member of the board of Fast Technology, there existed a business precedent according to which Mr. May assigned his invention to Fast Technology. In my opinion he had an organizational duty or at least an obligation of loyalty

to Fast Technology that required Mr. May to assign his inventions and the patent applications identified in Exhibit A to Fast Technology. Mr. May was paid by Fast Technology to work for the interests of Fast Technology, not for his own interests, and in fact, Mr. May always acted as if his inventions were owned by Fast Technology. For example, as described above, Mr. May was active in the invention and patenting process, I was told he was solely responsible for coordinating the preparation of patent applications and executing forms required by various patent offices around the world, including powers of attorney, assignments, and declaration forms, he used corporate assets to pay for the legal fees and government fees associated with patenting his inventions, and he identified Fast Technology as the "applicant" on those patent applications (except in the U.S., where he identified himself as the inventor/applicant in accordance with U.S. practice). Moreover, all of the inventions in Exhibit A relate to torque sensors, which was Fast Technology's primary field of operation when the company was doing business.

29. The ArbEG governs ownership of inventions made by "employees" working for German companies like Fast Technology. The law states that inventions made by German employees are regulated by mandatory provisions of the ArbEG. Since the law is mandatory, basically it is not subject to contractual modification by the parties, for example by an employment agreement. According to the contracts between Mr. May and Fast, the ArbEG accordingly applies, but not with regard to remuneration.

30. The ArbEG distinguishes between "service inventions," which are made during the period of employment and result either from the obligatory activity of the employee in a company or public authority, or are substantially based on experience and work carried out in the course of the employment, and "free inventions," which are all other inventions created by the employee during the period of employment.

31. If a service invention is made by an employee, the employee has a strict obligation to report it, without delay and in writing to the employer, stating that the report is notification of an invention. Within four months of receipt of the employee's notification, the employer may claim a restricted or unrestricted right to the invention. With an unrestricted claim, full title to the service invention is transferred to the employer with no further action on the employee's part as soon as the appropriate declaration is received. Irrespective of the provisions of the ArbEG, under German Law inventions and rights in inventions can be transferred in any form, especially tacitly or expressively, not necessarily in writing. A restricted claim leads to non-exclusive rights on the employer's behalf. Once the employer

has claimed the right to the employee's service inventions, the employee is entitled to a reasonable remuneration, which may be renounced by the employee. Once an invention is notified, the employer must then file a patent application at its expense.

32. With regard to free inventions, the employer may not claim a right in the inventions, but the employer must still be notified of a free invention in writing and without delay. No notice is required if the invention clearly has no application in the employer's field of operation. In some circumstances, the employee is required to offer the employer at least a non-exclusive right to use the inventions on reasonable conditions. If the ArbEG does not apply, the inventor retains all right to his inventions unless, as described previously, some other duty or obligation exists.

33. In this case, as an employee of Fast Technology, Mr. May had a duty under the ArbEG to fully and completely disclose his inventions to Fast Technology. Given that the applications identified in Exhibit A were submitted by Mr. May (through Fast Technology's patent attorneys) to respective patent offices around the world in the name of Fast Technology, Mr. May gave notice of those inventions to his employer without complying with the formalities of the ArbEG. Moreover, since Mr. May was in sole responsibility managing patent matters for Fast Technology, his entire behavior in context with the filing of the patent applications in my opinion was a tacit assignment over the inventions to Fast Technology.

34. With regard to the compensation requirement under the ArbEG, Mr. May disputes the fact that he was compensated for all of the inventions in Exhibit A. However, in my opinion Mr. May was compensated for his inventions he made as a managing director and/or a member of the board as part of his salary and bonuses given to him by Fast Technology in connection with his employment with those companies. Moreover, I was told that Mr. May received an amount of about DM 200,000.00 (or even €) as remuneration for the use of the inventions. Moreover, to the extent Mr. May did not seek further specific renumeration for the inventions that Fast Technology subsequently used, from the applicable point of view of Fast Technology his action was an unequivocal renouncement of any further right to compensation, something that is allowed under the ArbEG. To my mind he may not argue today that he was owed further renumeration from Fast Technology when he clearly waived his entitlement to the same by his earlier actions.

35. Without an order from the Munich Regional Court I clearing title in the patent applications identified in Exhibit A, Magna-Lastic Devices, Inc., and Abas, Inc., are

prevented from exploiting the Fast Technology inventions as a proprietor for which they paid a substantial amount of money in good faith pursuant to the August 22, 2003, Sales and Transfer Agreement in Exhibit C. Without this court order Magna-Lastic Devices Inc. and Abas Inc. cannot assert their rights in the inventions/patents in the relationship to third party using the inventions. These third parties would object that Magna-Lastic Devices Inc. and Abas Inc. are not the proprietors of these patents and therefore are not entitled to interdict such a use.

36. Accordingly, all of the inventions disclosed in Exhibit A, which were made by Mr. May in connection with his affiliation with Fast Technology, in my opinion were, as of August 22, 2003, owned by Fast Technology. Thus, when Magna-Lastic Devices, Inc., acquired the properties in Exhibit A from Fast Technology, it became the rightful owner of those properties. For those reasons, the Munich Regional Court I to my mind is likely to award the relief sought by Magna-Lastic Devices, Inc., and Abas, Inc., to include a declaration that Magna-Lastic Devices, Inc., or Abas, Inc., is the owner of the pending properties in Exhibit A and Mr. May is obliged to sign the assignments. In my opinion the Court is also likely to issue an Order that Mr. May clear title by executing assignment documents (and executing Declarations for Patent Application in U.S. cases) for each of the properties for which no assignment or Declaration has been executed to date.

Respectfully submitted,

Klaus Gennen

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Phone: 0221/55 400-170

LLR
LEGERLOTZ LASCHET
RECHTSANWÄLTE
Mevissenstraße 15
D-50668 Köln
Tel.: 02 21 / 55 40 00
Fax: 02 21 / 55 40 190

Date: _____

EXHIBIT A

ASSIGNMENT OF DOCUMENTS TO ABAS, INC.

ASSIGNMENT

WHEREAS, **FAST Technology AG**, a Germany company, having a principal place of business at Gewerbegebiet Riemerling, Otto-Hahn-Strasse 24, 85521 Ottobrunn, Germany, hereinafter referred to as ASSIGNOR, is the owner by assignment of the U.S. and foreign patent properties identified in Appendix A hereto (hereinafter referred to as the PATENT PROPERTIES).

WHEREAS, **Abas, Incorporated,** a Delaware corporation, having a principal place of business at 7401 W. Wilson Avenue, Chicago, Illinois 60706, hereinafter referred to as ASSIGNEE, is desirous of acquiring the entire right, title and interest in and to the same in the United States and around the world;

NOW, THEREFORE, for good and valuable consideration, receipt of which is hereby acknowledged, ASSIGNOR, by these presents does sell, assign and transfer unto said ASSIGNEE, the entire right, title, and interest in and to said PATENT PROPERTIES identified in the attached ~~Appendix A~~ LIST "B" throughout the United States of America and the world, including any and all United States Letters Patent granted on any division, continuation, continuation-in-part and reissue of said PATENT PROPERTIES; including the right to sue for past infringement; the right to apply for patents and inventor certificates in respect thereof and to claim priority pursuant to rights accorded ASSIGNOR under the terms of the Paris International Convention and all other available international conventions and treaties; and the entire right, title and interest in and to any and all patents, patents of addition, utility models, patents of importation, revalidation patents and inventor certificates which may be granted throughout the world in respect of said PATENT PROPERTIES.

ALSO, ASSIGNOR hereby agrees to execute any documents that legally may be required in connection with the filing, prosecution and maintenance of said application or any other patent application(s) or inventor certificate(s) in the United States and in foreign countries for said PATENT PROPERTIES, including additional documents that may be reasonably required to affirm the rights of ASSIGNEE in and to said PATENT PROPERTIES, all without further consideration. ASSIGNOR also agrees, without further consideration and at ASSIGNEE'S expense, to identify and communicate to ASSIGNEE at ASSIGNEE'S reasonable request documents and information concerning the PATENT PROPERTIES that are within ASSIGNOR'S possession or control, and to

provide further assurances and testimony on behalf of ASSIGNEE that lawfully may be required of ASSIGNOR in respect of the prosecution, maintenance and defense of any patent application or patent encompassed within the terms of this instrument. ASSIGNOR'S obligations under this instrument shall extend to ASSIGNOR'S heirs, executors, administrators and other legal representatives.

ASSIGNOR hereby authorizes and requests the Commissioner for Patents to issue any and all United States Letters Patent referred to above to ASSIGNEE, as the ASSIGNEE of the entire right, title and interest in and to the same, for ASSIGNEE'S sole use and behalf; and for the use and behalf of ASSIGNEE'S legal representatives and successors, to the full end of the term for which such Letters Patent may be granted, as fully and entirely as the same would have been held by ASSIGNOR had this assignment and sale not been made.

ASSIGNOR authorizes any member of the firm of **Blank Rome LLP** to insert or complete any information in this document needed to effect its recordal in the U.S. Patent & Trademark Office.

FAST Technology AG

[Signature]

GLEICHENSTEIN & BREITLING
Rechtsanwälte
Robert-Koch-Str. 40
80333 München
Telefon 0 89/54 27 30-0
Telefax 0 89/54 27 30-15
rae@gleichenstein-und-koll.de

Dr. Hans v. Gleichenstein

Authorized Agent

08.06.04

[Date]

LIST „B“

Kind of IPR	Application no./Registration no.	Country
Regional phase of PCT/GB99/00736	99907770.4	EP
Patent	6,581,480	US
Patent	2000-546211	JP
Regional phase of PCT/GB00/01103	00912776.2	EP
Patent	145533	IL
Patent	2000-606976	JP
Patent	09/937,230	US
National phase of EP 1203209	~~Not yet known~~ 60007641-C0	DE
National phase of EP 1203209	1203209	GB
Patent	148017	IL
Patent	2001-517133	JP
Patent	10/049,323	US
National phase of EP 1203210	60007641.5	DE
National phase of EP 1203210	1203210	GB
Patent	148016	IL
Patent	2001-517134	JP
Patent	10/049,322	US
Regional phase of PCT/EP00/09783	0971326.4	EP
Patent	148957	IL
Patent	2001-530597	JP
Patent	10/110,007	US
National phase of EP 1221030	60007540.0	DE
National phase of EP 1221030	1221030	GB
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International Application	Patent	PCT/EP03/04355	WO
Patent		10/419,995	US
International Application	Patent	PCT/EP03/09349	WO
International Application	Patent	PCT/EP03/10634	WO
Patent		02028056.6	EP
International Application	Patent	PCT/EP03/12104	WO
International Application	Patent	PCT/EP2004/00044	WO

EXHIBIT B

COPY OF RELEVANT STATUTE

Gesetz über Arbeitnehmererfindungen / Act on Employees' Inventions

Zweite Auflage / Second Edition

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Vorwort zur zweiten Auflage

Die rege Nachfrage hat eine zweite Auflage nach drei Jahren e
gemacht, obwohl sich seit der ersten Auflage bezüglich des Ges
Arbeitnehmererfindungen nur wenig geändert hat. Diese Änderun
fen die Behandlung der Arbeitnehmererfindungen im Insolvenzver
wurden in der zweiten Auflage berücksichtigt.

Um dem Leser einen kurzen Überblick über die Regelungen de
lung von Arbeitnehmererfindungen in einigen anderen, für den gev
Rechtsschutz bedeutsamen Ländern zu geben, wurde die zweit
um einen Abschnitt ergänzt, der eine Zusammenfassung der entsp
Bestimmungen in diesen Ländern enthält.

München, im März 2000

H. Reitzle
A. Butenschön
J. Bergmann

Preface to the second edition

Keen demand in the three years since publication of the first ed
led to a second edition even though there have been few changes i
of Employee's Inventions. The changes concern the treatment of en
inventions in insolvency proceedings. They are considered in th
edition.

To give the reader a short overview of the regulations of em
inventions in some other countries having important intellectual
laws, the second edition includes a passage summarizing the regul
these countries.

Munich, March 2000

H. Reitzle
A. Butenschön

Vorwort zur ersten Auflage

Durch die Verflechtung multinationaler Konzerne mit dem Forschungs- und Produktionsstandort Deutschland ist in jüngster Zeit vermehrt der Wunsch nach einer kompletten Übersetzung des Arbeitnehmer-Erfindergesetzes entstanden. Ursache hierfür ist die im internationalen Umfeld einzigartige Stellung dieser gesetzlichen Regelungen und damit verbundene Verständnisprobleme im Ausland. Dieses Buch, das eine englische Übersetzung in synoptischer Gegenüberstellung zum deutschen Text enthält, will diese Lücke schließen.

Das Buch wendet sich dabei sowohl an die Unternehmensleitungen und Patentabteilungen als auch an die beratenden Patentanwälte, um ihnen einen Überblick über die Regelungen des deutschen Arbeitnehmer-Erfindergesetzes zu vermitteln.

Eine kurze Einführung im Anschluß an den Gesetzestext soll dem Leser die Möglichkeit geben, sich einen Überblick über die einzelnen Bestimmungen und deren Zusammenhänge untereinander zu verschaffen.

Zur Erläuterung gesetzesspezifischer Begriffe enthält das Buch außerdem ein Glossar in deutscher und englischer Sprache mit entsprechenden Verweisen auf den Gesetzestext.

München, im März 1997

H. Reitzle
A. Butenschön
J. Bergmann

Preface to the first edition

Due to interlocking between multinational corporate entities and C
as an area of research and production, there has recently been an i
demand for a complete translation of the Act on Employees' Inv
The reason for this is the unique position of these legal regulation
international field, and the difficulties involved in understanding them
This book, which contains a simultaneously-opposed English transl
intended to fill this gap.

The book thus addresses business management and Patent departr
well as consulting Patent Attorneys, in order to give them an over
the regulations of the German Act on Employer's Inventions.

A short introduction preceding the text of the Act is intended to
reader an overview of the individual regulations and of their relatio
one another.

The book also contains a glossary in English and German with co
ding references to the legal text, in order to explain specific legal te

Munich, March 1997

H. Reitzle
A. Butenschön
J. Bergmann

Inhalt / Contents

Gesetz über Arbeitnehmererfindungen

Inhaltsübersicht

Act on Employees' Inventions

Contents

Der Bundestag hat das folgende Gesetz beschlossen:

Erster Abschnitt
Anwendungsbereich und Begriffsbestimmungen

§ 1 Anwendungsbereich

Diesem Gesetz unterliegen die Erfindungen und technischen Verbesserungsvorschläge von Arbeitnehmern im privaten und im öffentlichen Dienst, von Beamten und Soldaten.

§ 2 Erfindungen

Erfindungen im Sinne dieses Gesetzes sind nur Erfindungen, die patent- oder gebrauchsmusterfähig sind.

§ 3 Technische Verbesserungsvorschläge

Technische Verbesserungsvorschläge im Sinne dieses Gesetzes sind Vorschläge für sonstige technische Neuerungen, die nicht patent- oder gebrauchsmusterfähig sind.

§ 4 Diensterfindungen und freie Erfindungen

(1) Erfindungen von Arbeitnehmern im Sinne dieses Gesetzes können gebundene oder freie Erfindungen sein.

(2) Gebundene Erfindungen (Diensterfindungen) sind während der Dauer des Arbeitsverhältnisses gemachte Erfindungen, die entweder

1. aus der dem Arbeitnehmer im Betrieb oder in der öffentlichen Verwaltung obliegenden Tätigkeit entstanden sind oder
2. maßgeblich auf Erfahrungen von Arbeiten des Betriebes oder der öffentlichen Verwaltung beruhen.

(3) Sonstige Erfindungen von Arbeitnehmern sind freie Erfindungen. Sie unterliegen jedoch den Beschränkungen der §§ 18 und 19.

(4) Die Absätze 1 bis 3 gelten entsprechend für Erfindungen von Beamten und Soldaten.

The Bundestag has adopted the following Act:

First Section
Range of Application and Definition of Terms

§ 1 Field of Application

This Act covers the inventions and technical improvement pro employees in private employment and in the public sector, civil ser members of the armed forces.

§ 2 Inventions

Inventions within the meaning of this Act are only inventions v eligible for patent or utility model protection.

§ 3 Technical Improvement Proposals

Technical improvement proposals within the meaning of this proposals for other technical innovations which are not eligible f or utility model protection.

§ 4 Service Inventions and Free Inventions

(1) Inventions of employees within the meaning of this Act non-free or free inventions.

(2) Non-free inventions (service inventions) are inventions mad the period of employment which either

1. result from the obligatory activity of the employee in the cor public authority, or
2. are substantially based on experience or activities of the con public authority.

(3) Other inventions of employees are free inventions. However, subject to the restrictions of §§ 18 and 19.

(4) Paragraphs 1 to 3 apply accordingly for inventions of civil and members of the armed forces.

Zweiter Abschnitt
Erfindungen und technische Verbesserungsvorschläge von Arbeitnehmern im privaten Dienst

1. Diensterfindungen

§ 5 Meldepflicht

(1) Der Arbeitnehmer, der eine Diensterfindung gemacht hat, ist verpflichtet, sie unverzüglich dem Arbeitgeber gesondert schriftlich zu melden und hierbei kenntlich zu machen, daß es sich um die Meldung einer Erfindung handelt. Sind mehrere Arbeitnehmer an dem Zustandekommen der Erfindung beteiligt, so können sie die Meldung gemeinsam abgeben. Der Arbeitgeber hat den Zeitpunkt des Eingangs der Meldung dem Arbeitnehmer unverzüglich schriftlich zu bestätigen.

(2) In der Meldung hat der Arbeitnehmer die technische Aufgabe, ihre Lösung und das Zustandekommen der Diensterfindung zu beschreiben. Vorhandene Aufzeichnungen sollen beigefügt werden, soweit sie zum Verständnis der Erfindung erforderlich sind. Die Meldung soll dem Arbeitnehmer dienstlich erteilte Weisungen oder Richtlinien, die benutzten Erfahrungen oder Arbeiten des Betriebes, die Mitarbeiter sowie Art und Umfang ihrer Mitarbeit angeben und soll hervorheben, was der meldende Arbeitnehmer als seinen eigenen Anteil ansieht.

(3) Eine Meldung, die den Anforderungen des Absatzes 2 nicht entspricht, gilt als ordnungsgemäß, wenn der Arbeitgeber nicht innerhalb von zwei Monaten erklärt, daß und in welcher Hinsicht die Meldung einer Ergänzung bedarf. Er hat den Arbeitnehmer, soweit erforderlich, bei der Ergänzung der Meldung zu unterstützen.

§ 6 Inanspruchnahme

(1) Der Arbeitnehmer kann eine Diensterfindung unbeschränkt oder beschränkt in Anspruch nehmen.

(2) Die Inanspruchnahme erfolgt durch schriftliche Erklärung gegenüber dem Arbeitnehmer. Die Erklärung soll sobald wie möglich abgegeben werden; sie ist spätestens bis zum Ablauf von vier Monaten nach Eingang der ordnungsgemäßen Meldung (§ 5 Abs. 2 und 3) abzugeben.

§ 7 Wirkung der Inanspruchnahme

(1) Mit Zugang der Erklärung der unbeschränkten Inanspruchnahme gehen alle Rechte an der Diensterfindung auf den Arbeitgeber über.

Second Section
Inventions and Technical Improvement Proposals of Employee Private Employment

1. Service Inventions

§ 5 Obligation to Report

(1) The employee who has made a service invention is obliged to separately in writing without delay to the employer, and with this gi that said report constitutes the report of an invention. If several er are involved in the creation of the invention, then they can submit t jointly. The employer must acknowledge the time of receipt of the writing to the employee without delay.

(2) The employee must describe the technical object, its solution creation of the service invention in the report. Existing notes shall be as far as they are necessary for understanding the invention. The rep specify any instructions or guidelines issued to the employee by the c any experience or activities of the company used, the co-workers as well as the type and scope of their involvement, and shall emphas the reporting employee regards as his own contribution.

(3) Any report which does not correspond to the requirements in pa 2 shall be considered in order if the employer does not declare two months that the report requires completion and in which reg is the case. He must provide assistance to the employee, where neces completion of the report.

§ 6 Claiming Right

(1) The employer can claim the right to a service invention unrestricted or restricted basis.

(2) The claiming of right occurs by written declaration to the em The declaration shall be submitted as soon as possible, and no later th months from the receipt of the proper report (§ 5 para. 2 and 3).

§ 7 Effect of Claiming Right

(1) On receipt of the declaration of unrestricted claiming of right al on the service invention are transferred to the employer.

(2) Mit Zugang der Erklärung der beschränkten Inanspruchnahme erwirbt der Arbeitgeber nur ein nichtausschließliches Recht zur Benutzung der Diensterfindung. Wird durch das Benutzungsrecht des Arbeitgebers die anderweitige Verwertung der Diensterfindung durch den Arbeitnehmer unbillig erschwert, so kann der Arbeitnehmer verlangen, daß der Arbeitgeber innerhalb von zwei Monaten die Diensterfindung entweder unbeschränkt in Anspruch nimmt oder sie dem Arbeitnehmer freigibt.

(3) Verfügungen, die der Arbeitnehmer über eine Diensterfindung vor der Inanspruchnahme getroffen hat, sind dem Arbeitgeber gegenüber unwirksam, soweit seine Rechte beeinträchtigt werden.

§ 8 Frei gewordene Diensterfindungen

(1) Eine Diensterfindung wird frei,
1. wenn der Arbeitgeber sie schriftlich freigibt;
2. wenn der Arbeitgeber sie beschränkt in Anspruch nimmt, unbeschadet das Benutzungsrecht des Arbeitgebers nach § 7 Abs. 2;
3. wenn der Arbeitgeber sie nicht innerhalb von vier Monaten nach Eingang der ordnungsgemäßen Meldung (§ 5 Abs. 2 und 3) oder im Falle des § 7 Abs. 2 innerhalb von zwei Monaten nach dem Verlangen des Arbeitnehmers in Anspruch nimmt.

(2) Über eine frei gewordene Diensterfindung kann der Arbeitnehmer ohne die Beschränkungen der §§ 18 und 19 verfügen.

§ 9 Vergütung bei unbeschränkter Inanspruchnahme

(1) Der Arbeitnehmer hat gegen den Arbeitgeber einen Anspruch auf angemessene Vergütung, sobald der Arbeitgeber die Diensterfindung unbeschränkt in Anspruch genommen hat.

(2) Für die Bemessung der Vergütung sind insbesondere die wirtschaftliche Verwertbarkeit der Diensterfindung, die Aufgaben und die Stellung des Arbeitnehmers im Betrieb, sowie der Anteil des Betriebes an dem Zustandekommen der Diensterfindung maßgebend.

§ 10 Vergütung bei beschränkter Inanspruchnahme

(1) Der Arbeitnehmer hat gegen den Arbeitgeber einen Anspruch auf angemessene Vergütung, sobald der Arbeitgeber die Diensterfindung beschränkt in Anspruch genommen hat und sie benutzt. § 9 Abs. 2 ist entsprechend anzuwenden.

(2) On receipt of the declaration of restricted claiming of right the only acquires a non-exclusive right to utilisation of the service inv the utilisation of the service invention elsewhere by the employee is unjustly difficult by the right of use of the employer, then the empl demand that the employer either claims the right to the service within two months without restriction or releases it to the employ

(3) Any dispositions the employee has made concerning a service prior to the claiming of right are ineffective with respect to the en far as his rights are encroached upon.

§ 8 Released Service Inventions

(1) A service invention becomes free:
1. when the employer releases it in writing;
2. when the employer claims the right to it with restriction prejudice to the utilisation right of the employer in accorda § 7 para. 2;
3. when the employer does not claim the right to it within fou from receipt of the proper report (§ 5 para. 2 and 3) or in th § 7 para. 2, within two months on demand of the employee.

(2) The employee can make use of a released service invention the restrictions of §§ 18 and 19.

§ 9 Remuneration with Unrestricted Claiming of Right

(1) The employee has a claim to reasonable remuneration ag employer as soon as the employer has claimed the right to th invention without restriction.

(2) Decisive factors for calculating the remuneration in particul economic exploitability of the service invention, the duties and p the employee in the company and also the degree of involveme company in the creation of the service invention.

§ 10 Remuneration with Restricted Claiming of Right

(1) The employee has a claim to reasonable remuneration a employer as soon as the employer has claimed the right to th invention with restriction and uses it. § 9 para. 2 should be applie mutandis.

(2) Nach Inanspruchnahme der Diensterfindung kann sich der Arbeitgeber dem Arbeitnehmer gegenüber nicht darauf berufen, daß die Erfindung zur Zeit der Inanspruchnahme nicht schutzfähig gewesen sei, es sei denn, daß sich dies aus einer Entscheidung des Patentamts oder eines Gerichts ergibt. Der Vergütungsanspruch des Arbeitnehmers bleibt unberührt, soweit er bis zur rechtskräftigen Entscheidung fällig geworden ist.

§ 11 Vergütungsrichtlinien

Der Bundesminister für Arbeit erläßt nach Anhörung der Spitzenorganisationen der Arbeitgeber und der Arbeitnehmer (§ 10a des Tarifvertragsgesetzes) Richtlinien über die Bemessung der Vergütung.

§ 12 Feststellung oder Festsetzung der Vergütung

(1) Die Art und Höhe der Vergütung soll in angemessener Frist nach Inanspruchnahme der Diensterfindung durch Vereinbarung zwischen dem Arbeitgeber und dem Arbeitnehmer festgestellt werden.

(2) Wenn mehrere Arbeitnehmer an der Diensterfindung beteiligt sind, ist die Vergütung für jeden gesondert festzustellen. Die Gesamthöhe der Vergütung und die Anteile der einzelnen Erfinder an der Diensterfindung hat der Arbeitgeber den Beteiligten bekanntzugeben.

(3) Kommt eine Vereinbarung über die Vergütung in angemessener Frist nach Inanspruchnahme der Diensterfindung nicht zustande, so hat der Arbeitgeber die Vergütung durch eine begründete schriftliche Erklärung an den Arbeitnehmer festzusetzen und entsprechend der Festsetzung zu zahlen. Bei unbeschränkter Inanspruchnahme der Diensterfindung ist die Vergütung spätestens bis zum Ablauf von drei Monaten nach Erteilung des Schutzrechts, bei beschränkter Inanspruchnahme spätestens bis zum Ablauf von drei Monaten nach Aufnahme der Benutzung festzusetzen.

(4) Der Arbeitnehmer kann der Festsetzung innerhalb von zwei Monaten durch schriftliche Erklärung widersprechen, wenn er mit der Festsetzung nicht einverstanden ist. Widerspricht er nicht, so wird die Festsetzung für beide Teile verbindlich.

(5) Sind mehrere Arbeitnehmer an der Diensterfindung beteiligt, so wird die Festsetzung für alle Beteiligten nicht verbindlich, wenn einer von ihnen der Festsetzung mit der Begründung widerspricht, daß sein Anteil an der Diensterfindung unrichtig festgesetzt sei. Der Arbeitgeber ist in diesem Fall berechtigt, die Vergütung für alle Beteiligten neu festzusetzen.

(2) After the right to the service invention has been claimed, t
cannot plead to the employee that the invention was not eligible f
at the time of the claiming of right, unless this results from a decis
Patent Office or a court. The claim to remuneration of the emplo
unaffected as far as it has fallen due until the legally valid deci

§ 11 Remuneration Guidelines

The Federal Minister of Labor issues guidelines concerning ca
remuneration after hearing the leading organisations of the em
employees (§ 10a of the Collective Agreements Law).

§ 12 Establishing or Fixing the Remuneration

(1) The type and amount of remuneration shall be establishe by
between the employer and the employee in a reasonable perio
claiming of right to the service invention.

(2) If several employees are involved in the service inventio, re
must be established for each of them separately. The employer
those involved of the total amount of remuneration and the sh
individual inventors in the service invention.

(3) If no agreement is reached concerning remuneration within a
period after claiming of right to the service invention, then the
must fix remuneration by way of a substantiated written declara
employee and must pay in accordance with the fixation. In t
unrestricted claiming of right to the service invention, remunerati
fixed at the latest by the expiry of three months after grant of the
right, and in the case of restricted claiming of right at the latest by
of three months after commencement of use.

(4) The employee can contest the fixation within two months
declaration, if he is not in agreement with the fixation. If he does
it, then the fixation is binding for both parties.

(5) If several employees are involved in the service invention
fixation is not binding for all parties, if one of them contests the f
the grounds that his share in the service invention has been fixed i
The employer is entitled in this case to fix the remuneration for
anew.

(6) Arbeitgeber und Arbeitnehmer können voneinander die Einwilligung in eine andere Regelung der Vergütung verlangen, wenn sich Umstände wesentlich ändern, die für die Feststellung oder Festsetzung der Vergütung maßgebend waren. Rückzahlung einer bereits geleisteten Vergütung kann nicht verlangt werden. Die Absätze 1 bis 5 sind nicht anzuwenden.

§ 13 Schutzrechtsanmeldung im Inland

(1) Der Arbeitgeber ist verpflichtet und allein berechtigt, eine gemeldete Diensterfindung im Inland zur Erteilung eines Schutzrechts anzumelden. Eine patentfähige Diensterfindung hat er zur Erteilung eines Patentes anzumelden, sofern nicht bei verständiger Würdigung der Verwertbarkeit der Erfindung der Gebrauchsmusterschutz zweckdienlicher erscheint. Die Anmeldung hat unverzüglich zu geschehen.

(2) Die Verpflichtung des Arbeitgebers zur Anmeldung entfällt,

1. wenn die Diensterfindung frei geworden ist (§ 8 Abs.1);
2. wenn der Arbeitnehmer der Nichtanmeldung zustimmt;
3. wenn die Voraussetzungen des § 17 vorliegen.

(3) Genügt der Arbeitgeber nach unbeschränkter Inanspruchnahme der Diensterfindung seiner Anmeldepflicht nicht und bewirkt er die Anmeldung auch nicht innerhalb einer ihm vom Arbeitnehmer gesetzten angemessenen Nachfrist, so kann der Arbeitnehmer die Anmeldung der Diensterfindung für den Arbeitgeber auf dessen Namen und Kosten bewirken.

(4) Ist die Diensterfindung frei geworden, so ist nur der Arbeitnehmer berechtigt, sie zur Erteilung eines Schutzrechts anzumelden. Hatte der Arbeitgeber die Diensterfindung bereits zur Erteilung eines Schutzrechts angemeldet, so gehen die Rechte aus der Anmeldung auf den Arbeitnehmer über.

§ 14 Schutzrechtsanmeldung im Ausland

(1) Nach unbeschränkter Inanspruchnahme der Diensterfindung ist der Arbeitgeber berechtigt, diese auch im Ausland zur Erteilung von Schutzrechten anzumelden.

(2) Für ausländische Staaten, in denen der Arbeitgeber Schutzrechte nicht erwerben will, hat er dem Arbeitnehmer die Diensterfindung freizugeben und ihm auf Verlangen den Erwerb von Auslandsschutzrechten zu ermöglichen. Die Freigabe soll so rechtzeitig vorgenommen werden, daß der Arbeitnehmer die Prioritätsfristen der zwischenstaatlichen Verträge auf dem Gebiet des gewerblichen Rechtsschutzes ausnutzen kann.

(6) Employer and employee can require one another to consent t
settlement of the remuneration if there is a substantial change i
stances which were decisive for establishing or fixing the remu
Repayment of remuneration already effected cannot be demanded. P
1 to 5 are not to be applied.

§ 13 Domestic Application for Protective Right

(1) The employer is obliged and alone entitled to apply for a
service invention for grant of a domestic protective right. He m
for grant of a patent for a patentable service invention unless prot
means of utility model appears more appropriate on reasonable eval
the exploitability of the invention. Application must occur without

(2) The obligation of the employer to submit an application is i
ble:

1. when the service invention has become free (§ 8 para. 1);
2. when the employee agrees to non-submission of an applicatio
3. when the conditions of § 17 exist.

(3) If after unrestricted claiming of right to the service inver
employer does not meet his obligation to apply and he does not
application within a reasonable subsequent period set by the employ
the employee can effect the application for the service invention
employer in the latter's name and at the latter's cost.

(4) If the service invention has become free, then only the emp
entitled to apply for it for grant of a protective right. If the emplo
already applied for the service invention for grant of a protective ri
the rights from the application are transferred to the employee.

§ 14 Foreign Application for Protective Right

(1) After unrestricted claiming of right for the service invent
employer is entitled to also apply for this abroad for grant of pr
rights.

(2) For foreign states in which the employer does not wish to
protective rights, he must release the service invention to the emplo
allow him the aquisition of foreign protective rights on demand.
should be undertaken sufficiently promptly to allow the employee t
use of the priority periods of the treaties between countries in the
legal protection for industrial property.

(3) Der Arbeitgeber kann sich gleichzeitig mit der Freigabe nach Absatz 2 ein nichtausschließliches Recht zur Benutzung der Diensterfindung in den betreffenden ausländischen Staaten gegen angemessene Vergütung vorbehalten und verlangen, daß der Arbeitnehmer bei der Verwertung der freigegebenen Erfindung in den betreffenden ausländischen Staaten die Verpflichtungen des Arbeitgebers aus den im Zeitpunkt der Freigabe bestehenden Verträgen über die Diensterfindung gegen angemessene Vergütung berücksichtigt.

§ 15 Gegenseitige Rechte und Pflichten beim Erwerb von Schutzrechten

(1) Der Arbeitgeber hat dem Arbeitnehmer zugleich mit der Anmeldung der Diensterfindung zur Erteilung eines Schutzrechts Abschriften der Anmeldeunterlagen zu geben. Er hat ihn von dem Fortgang des Verfahrens zu unterrichten und ihm auf Verlangen Einsicht in den Schriftwechsel zu gewähren.

(2) Der Arbeitnehmer hat den Arbeitgeber auf Verlangen beim Erwerb von Schutzrechten zu unterstützen und die erforderlichen Erklärungen abzugeben.

§ 16 Aufgabe der Schutzrechtsanmeldung oder des Schutzrechts

(1) Wenn der Arbeitgeber vor Erfüllung des Anspruchs des Arbeitnehmers auf angemessene Vergütung die Anmeldung der Diensterfindung zur Erteilung eines Schutzrechts nicht weiterverfolgen oder das auf die Diensterfindung erteilte Schutzrecht nicht aufrechterhalten will, hat er dies dem Arbeitnehmer mitzuteilen und ihm auf dessen Verlangen und Kosten das Recht zu übertragen sowie die zur Wahrung des Rechts erforderlichen Unterlagen auszuhändigen.

(2) Der Arbeitgeber ist berechtigt, das Recht aufzugeben, sofern der Arbeitnehmer nicht innerhalb von drei Monaten nach Zugang der Mitteilung die Übertragung des Rechts verlangt.

(3) Gleichzeitig mit der Mitteilung nach Absatz 1 kann sich der Arbeitgeber ein nichtausschließliches Recht zur Benutzung der Diensterfindung gegen angemessene Vergütung vorbehalten.

(3) At the same time as the release in accordance with paragra employer can reserve a non-exclusive right to utilise the service i in the relevant foreign states for reasonable remuneration and den the employee respects the obligations of the employer from the ag existing at the time of release concerning the service invention for re remuneration when exploiting the released invention in the relevan states.

§ 15 Mutual Rights and Obligations in the Acquisition of Prot Rights

(1) The employer must provide the employee with copies of the ap documents at the same time as the application of the service inver grant of a protective right is filed. The employer must advise hir progress of the procedure and allow him insight into the correspond demand.

(2) The employee must assist the employer on demand in the acc of protective rights and provide the necessary declarations.

§ 16 Abandonment of the Application for Protective Right or c Protective Right

(1) If, prior to meeting the claim of the employee for rea remuneration, the employer does not wish to pursue the application service invention for grant of a protective right or does not wish to r the protective right granted for the service invention, he must infc employee of this and transfer the right to him on the latter's demanc the latter's cost, as well as provide him with the necessary docum safeguarding the right.

(2) The employer is entitled to surrender the right if the employ not demand transfer of the right within three months from receipt notice.

(3) At the same time as the notice according to paragraph 1, the en may reserve a non-exclusive right to use of the service invent reasonable remuneration.

§ 17 Betriebsgeheimnisse

(1) Wenn berechtigte Belange des Betriebes es erfordern, eine gemeldete Diensterfindung nicht bekanntwerden zu lassen, kann der Arbeitgeber von der Erwirkung eines Schutzrechts absehen, sofern er die Schutzfähigkeit der Diensterfindung gegenüber dem Arbeitnehmer anerkennt.

(2) Erkennt der Arbeitgeber die Schutzfähigkeit der Diensterfindung nicht an, so kann er von der Erwirkung eines Schutzrechts absehen, wenn er zur Herbeiführung einer Einigung über die Schutzfähigkeit der Diensterfindung die Schiedsstelle (§ 29) anruft.

(3) Bei der Bemessung der Vergütung für eine Erfindung nach Absatz 1 sind auch die wirtschaftlichen Nachteile zu berücksichtigen, die sich für den Arbeitnehmer daraus ergeben, daß auf die Diensterfindung kein Schutzrecht erteilt worden ist.

2. Freie Erfindungen

§ 18 Mitteilungspflicht

(1) Der Arbeitnehmer, der während der Dauer des Arbeitsverhältnisses eine freie Erfindung gemacht hat, hat dies dem Arbeitgeber unverzüglich schriftlich mitzuteilen. Dabei muß über die Erfindung und, wenn dies erforderlich ist, auch über ihre Entstehung so viel mitgeteilt werden, daß der Arbeitgeber beurteilen kann, ob die Erfindung frei ist.

(2) Bestreitet der Arbeitgeber nicht innerhalb von drei Monaten nach Zugang der Mitteilung durch schriftliche Erklärung an den Arbeitnehmer, daß die ihm mitgeteilte Erfindung frei sei, so kann er die Erfindung nicht mehr als Diensterfindung in Anspruch nehmen.

(3) Eine Verpflichtung zur Mitteilung freier Erfindungen besteht nicht, wenn die Erfindung offensichtlich im Arbeitsbereich des Betriebes des Arbeitgebers nicht verwendbar ist.

§ 19 Anbietungspflicht

(1) Bevor der Arbeitnehmer eine freie Erfindung während der Dauer des Arbeitsverhältnisses anderweitig verwertet, hat er zunächst dem Arbeitgeber mindestens ein nichtausschließliches Recht zur Benutzung der Erfindung zu angemessenen Bedingungen anzubieten, wenn die Erfindung im Zeitpunkt des Angebots in den vorhandenen oder vorbereiteten Arbeitsbereich des Betriebes des Arbeitgebers fällt. Das Angebot kann gleichzeitig mit der Mitteilung nach § 18 abgegeben werden.

§ 17 Trade Secrets

(1) If legitimate interests of the company require that a repo invention should not be made known, the employer can re obtainment of a protective right so long as he acknowledges th of the service invention for protection to the employee.

(2) If the employer does not acknowledge the eligibility of invention for protection, then he may refrain from obtainment of right if he appeals to the Board of Arbitration (§ 29) to brin agreement concerning the eligibility of the service invention for p

(3) The economic disadvantages, which result for the employe fact that no protective right had been granted for the service inve also be taken into consideration in the calculation of the remuner invention in accordance with paragraph 1.

2. Free Inventions

§ 18 Obligation to Give Notice

(1) The employee who has made a free invention during the employment must notify the employer of this in writing withou this case, a sufficient amount of information concerning the inven necessary, also concerning its creation, must be given so that th can judge whether the invention is free.

(2) If the employer does not dispute within three months from the notice by written declaration to the employee that the invention him is free, then he can no longer claim the invention as a service in

(3) There is no obligation to give notice of free inventions if th is obviously not usable in the field of operations of the comp employer.

§ 19 Obligation to Offer

(1) Before the employee exploits a free invention elsewhere period of employment, he must first offer the employer at le exclusive right to the use of the invention at reasonable conditio time of the offer the invention falls within the existing or in pro of operation of the company of the employer. The offer can be simultaneously with the notice in accordance with § 18.

(2) Nimmt der Arbeitgeber das Angebot innerhalb ..n drei Monaten nicht an, so erlischt das Vorrecht.

(3) Erklärt sich der Arbeitgeber innerhalb der Frist des Absatzes 2 zum Erwerb des ihm angebotenen Rechts bereit, macht er jedoch geltend, daß die Bedingungen des Angebots nicht angemessen seien, so setzt das Gericht auf Antrag des Arbeitgebers oder des Arbeitnehmers die Bedingungen fest.

(4) Der Arbeitgeber oder der Arbeitnehmer kann eine andere Festsetzung der Bedingungen beantragen, wenn sich Umstände wesentlich ändern, die für die vereinbarten oder festgesetzten Bedingungen maßgebend waren.

3. Technische Verbesserungsvorschläge

§ 20 Technische Verbesserungsvorschläge

(1) Für technische Verbesserungsvorschläge, die dem Arbeitgeber eine ähnliche Vorzugsstellung gewähren wie ein gewerbliches Schutzrecht, hat der Arbeitnehmer gegen den Arbeitgeber einen Anspruch auf angemessene Vergütung, sobald dieser sie verwertet. Die Bestimmungen der §§ 9 und 12 sind sinngemäß anzuwenden.

(2) Im übrigen bleibt die Behandlung technischer Verbesserungsvorschläge der Regelung durch Tarifvertrag oder Betriebsvereinbarung überlassen.

4. Gemeinsame Bestimmungen

§ 21 Erfinderberater

(1) In Betrieben können durch Übereinkunft zwischen Arbeitgeber und Betriebsrat ein oder mehrere Erfinderberater bestellt werden.

(2) Der Erfinderberater soll insbesondere den Arbeitnehmer bei der Abfassung der Meldung (§ 5) oder der Mitteilung (§ 18) unterstützen sowie auf Verlangen des Arbeitgebers und des Arbeitnehmers bei der Ermittlung einer angemessenen Vergütung mitwirken.

§ 22 Unabdingbarkeit

Die Vorschriften dieses Gesetzes können zuungunsten des Arbeitnehmers nicht abgedungen werden. Zulässig sind jedoch Vereinbarungen über Diensterfindungen nach ihrer Meldung, über freie Erfindungen und technische Verbesserungsvorschläge (§ 20 Abs. 1) nach ihrer Mitteilung.

(2) If the e loyer does not accept the offer within three month privilege lapses.

(3) If the employer agrees to acquire the right offered to him period specified in paragraph 2, but asserts that the conditions of are not reasonable, then the court shall fix conditions upon requ employer or employee.

(4) The employer or employee may request a different fixati conditions if there is a substantial change in the circumstances w decisive for the agreed or fixed conditions.

3. Technical Improvement Proposals

§ 20 Technical Improvement Proposals

(1) For technical improvement proposals which assure the emp similar preferential position as an industrial protective right, the has a claim for reasonable remuneration against the employer a the employer exploits it. The regulations of §§ 9 and 12 should b mutatis mutandis.

(2) The handling of technical improvement proposals is otherwi to regulation by collective agreement or company agreement.

4. Common Provisions

§ 21 Inventor's Advisers

(1) One or more inventor's advisers may be called upon in com agreement between the employer and employees' council.

(2) The inventor's adviser shall in particular assist the employee i the report (§5) or the notice (§ 18) as well as assist in the determ a reasonable remuneration on demand of the employer and the em

§ 22 Inalienability

The provisions of the Act may not be altered to the detrime employee. However, agreements concerning service inventions are after they have been reported, and agreements concerning free inver technical improvement proposals (§ 20 para. 1) are permitted after i been given of them.

§ 23 Unbilligkeit

(1) Vereinbarungen über Diensterfindungen, freie Erfindungen oder technische Verbesserungsvorschläge (§ 20 Abs. 1), die nach diesem Gesetz zulässig sind, sind unwirksam, soweit sie in erheblichen Maße unbillig sind. Das gleiche gilt für die Festsetzung der Vergütung (§ 12 Abs. 4).

(2) Auf die Unbilligkeit einer Vereinbarung oder einer Festsetzung der Vergütung können sich Arbeitgeber und Arbeitnehmer nur berufen, wenn sie die Unbilligkeit spätestens bis zum Ablauf von sechs Monaten nach Beendigung des Arbeitsverhältnisses durch schriftliche Erklärung gegenüber dem anderen Teil geltend machen.

§ 24 Geheimhaltungspflicht

(1) Der Arbeitgeber hat die ihm gemeldete oder mitgeteilte Erfindung eines Arbeitnehmers so lange geheimzuhalten, als dessen berechtigte Belange dies erfordern.

(2) Der Arbeitnehmer hat eine Diensterfindung so lange geheimzuhalten, als sie nicht frei geworden ist (§ 8 Abs. 1).

(3) Sonstige Personen, die auf Grund dieses Gesetzes von einer Erfindung Kenntnis erlangt haben, dürfen ihre Kenntnis weder auswerten noch bekanntgeben.

§ 25 Verpflichtungen aus dem Arbeitsverhältnis

Sonstige Verpflichtungen, die sich für den Arbeitgeber und den Arbeitnehmer aus dem Arbeitsverhältnis ergeben, werden durch die Vorschriften dieses Gesetzes nicht berührt, soweit sich nicht daraus, daß die Erfindung frei geworden ist (§ 8 Abs. 1), etwas anderes ergibt.

§ 26 Auflösung des Arbeitsverhältnisses

Die Rechte und Pflichten aus diesem Gesetz werden durch die Auflösung des Arbeitsverhältnisses nicht berührt.

§ 27 Insolvenzverfahren

Wird nach unbeschränkter Inanspruchnahme der Diensterfindung das Insolvenzverfahren über das Vermögen des Arbeitgebers eröffnet, so gilt folgendes:

(1) Veräußert der Insolvenzverwalter die Diensterfindung mit dem Geschäftsbetrieb, so tritt der Erwerber für die Zeit von der Eröffnung des Insolvenzverfahrens an in die Vergütungspflicht des Arbeitgebers (§ 9) ein.

§ 23 Inequi

(1) Agreements concerning service inventions, free inventions o improvement proposals (§ 20 para. 1) permissible according to th void if they are substantially inequitable. The same applies for th of the remuneration (§ 12 para. 4).

(2) The employer and employee may only call upon inequ agreement or a fixation of remuneration if they make the assertion o by written declaration to the other party at the latest by the exp months from the end of the employment.

§ 24 Obligation to Secrecy

(1) The employer must keep secret any invention of an employee or notified to him as long as the employee's legitimate interest req

(2) The employee must keep secret a service invention for so l has not become free (§ 8 para. 1).

(3) Other persons who have obtained knowledge of an inventio basis of this Act may neither exploit their knowledge nor make it k

§ 25 Obligations from Employment

Other obligations resulting for the employer and employee from ment are not affected by the provisions of this Act if nothing differe from the invention being released (§ 8 para. 1).

§ 26 Dissolution of Employment

The rights and obligations from this Act are not affected by the di of employment.

§ 27 Insolvency proceedings

If, after unrestricted claim to the employee's invention, ins proceedings are instituted against the employer, the following applie

(1) If the receiver sells the employee's invention with the busin buyer enters into the employer's obligation to pay remuneration (§ 9 period from institution of insolvency proceedings onwards.

(2) Veräußert der Insolvenzverwalter die Diensterfindung ohne den Geschäftsbetrieb, so hat der Arbeitnehmer ein Vorkaufsrecht. Übt der Arbeitnehmer das Vorkaufsrecht aus, so kann er mit seinen Ansprüchen auf Vergütung für die unbeschränkte Inanspruchnahme der Diensterfindung gegen die Kaufpreisforderung aufrechnen. Für den Fall, daß der Arbeitnehmer das Vorkaufsrecht nicht ausübt, kann der Insolvenzverwalter mit dem Erwerber vereinbaren, daß sich dieser verpflichtet, dem Arbeitnehmer eine angemessene Vergütung (§ 9) für die weitere Verwertung der Diensterfindung zu zahlen. Wird eine solche Vereinbarung nicht getroffen, so erhält der Arbeitnehmer eine angemessene Abfindung aus dem Veräußerungserlös.

(3) Verwertet der Insolvenzverwalter die Diensterfindung im Unternehmen des Schuldners, so hat er dem Arbeitnehmer eine angemessene Vergütung für die Verwertung aus der Insolvenzmasse zu zahlen.

(4) Will der Insolvenzverwalter die Diensterfindung weder im Unternehmen des Schuldners verwerten noch veräußern, so gilt § 16 Abs. 1 und 2 entsprechend. Verlangt der Arbeitnehmer die Übertragung der Erfindung, so kann er mit seinen Ansprüchen auf Vergütung für die unbeschränkte Inanspruchnahme der Diensterfindung gegen den Anspruch auf Erstattung der Kosten der Übertragung aufrechnen.

(5) Im übrigen kann der Arbeitnehmer seine Vergütungsansprüche nur als Insolvenzgläubiger geltend machen.

5. Schiedsverfahren

§ 28 Gütliche Einigung

In allen Streitfällen zwischen Arbeitgeber und Arbeitnehmer auf Grund dieses Gesetzes kann jederzeit die Schiedsstelle angerufen werden. Die Schiedsstelle hat zu versuchen, eine gütliche Einigung herbeizuführen.

§ 29 Errichtung der Schiedsstelle

(1) Die Schiedsstelle wird beim Patentamt errichtet.
(2) Die Schiedsstelle kann außerhalb ihres Sitzes zusammentreten.

§ 30 Besetzung der Schiedsstelle

(1) Die Schiedsstelle besteht aus einem Vorsitzenden oder seinem Vertreter und zwei Beisitzern.

(2) If the receiver sells the employee's invention without the busi employee has a preemptive right. If the employee exercises the pr right, he may offset his claims to remuneration for the unlimited cla employee's invention, against the purchase price demand. In the e the employee does not exercise the preemptive right, the receiver m with the buyer that the latter should undertake to pay reasonable remu (§ 19) to the employee for further exploitation of the employee's inve no such agreement is made, the employee receives reasonable comp from the proceeds of the sale.

(3) If the receiver exploits the employee's invention in the company, he must pay the employee reasonable remuneration exploitation out of the insolvent's estate.

(4) If the receiver wishes neither to exploit the employee's invention debtor's company nor sell it, then § 16 paras. 1 and 2 shall apply co If the employee demands assignment of the invention, he may of claims to remuneration for the unlimited claim to the employee's in against the claim to reimbursement for the costs of assignment.

(5) Moreover the employee may lodge his claims to remuneration an insolvency creditor.

5. Arbitration Procedure

§ 28 Amicable Settlement

The Board of Arbitration may be called upon at any time in all ca dispute between the employer and employee on the basis of this Ac Board of Arbitration must attempt to bring about an amicable agreem

§ 29 Establishment of the Board of Arbitration

(1) The Board of Arbitration is set up at the Patent Office.
(2) The Board of Arbitration may meet outside its domicile.

§ 30 Composition of the Board of Arbitration

(1) The Board of Arbitration consists of a Chairman or his substitut two assessors.

(2) Der Vorsitzende und sein Vertreter sollen die Befähigung zum Richteramt nach dem Gerichtsverfassungsgesetz besitzen. Sie werden vom Bundesminister für Justiz am Beginn des Kalenderjahres für dessen Dauer berufen.

(3) Die Beisitzer sollen auf dem Gebiet der Technik, auf das sich die Erfindung oder der technische Verbesserungsvorschlag bezieht, besondere Erfahrung besitzen. Sie werden vom Präsidenten des Patentamts aus den Mitgliedern oder Hilfsmitgliedern des Patentamts für den einzelnen Streitfall berufen.

(4) Auf Antrag eines Beteiligten ist die Besetzung der Schiedsstelle um je einen Beisitzer aus Kreisen der Arbeitgeber und der Arbeitnehmer zu erweitern. Diese Beisitzer werden vom Präsidenten des Patentamts aus Vorschlagslisten ausgewählt und für den einzelnen Streitfall bestellt. Zur Einreichung von Vorschlagslisten sind berechtigt die im § 11 genannten Spitzenorganisationen, ferner die Gewerkschaften und die selbständigen Vereinigungen von Arbeitnehmern mit sozial- oder berufspolitischer Zwecksetzung, die keiner dieser Spitzenorganisationen angeschlossen sind, wenn ihnen eine erhebliche Zahl von Arbeitnehmern angehört, von denen nach der ihnen im Betrieb obliegenden Tätigkeit erfinderische Leistungen erwartet werden.

(5) Der Präsident des Patentamts soll den Beisitzer nach Absatz 4 aus der Vorschlagsliste derjenigen Organisation auswählen, welcher der Beteiligte angehört, wenn der Beteiligte seine Zugehörigkeit zu einer Organisation vor der Auswahl der Schiedsstelle mitgeteilt hat.

(6) Die Dienstaufsicht über die Schiedsstelle führt der Vorsitzende, die Dienstaufsicht über den Vorsitzenden der Bundesminister für Justiz.

§ 31 Anrufung der Schiedsstelle

(1) Die Anrufung der Schiedsstelle erfolgt durch schriftlichen Antrag. Der Antrag soll in zwei Stücken eingereicht werden. Er soll eine kurze Darstellung des Sachverhaltes sowie Namen und Anschrift des anderen Beteiligten enthalten.

(2) Der Antrag wird vom Vorsitzenden der Schiedsstelle dem anderen Beteiligten mit der Aufforderung zugestellt, sich innerhalb einer bestimmten Frist zu dem Antrag schriftlich zu äußern.

§ 32 Antrag auf Erweiterung der Schiedsstelle

Der Antrag auf Erweiterung der Besetzung der Schiedsstelle ist von demjenigen, der die Schiedsstelle anruft, zugleich mit der Anrufung (§ 31 Abs. 1), von dem anderen Beteiligten innerhalb von zwei Wochen nach Zustellung des die Anrufung enthaltenden Antrags (§ 31 Abs. 2) zu stellen.

(2) The Chairman and his substitute shall have the quali justiceship required according to the Judiciary Act. They are a the Federal Minister of Justice at the beginning of the calendar duration.

(3) The assessors shall have special experience in the techni which the invention or the technical improvement proposal relate appointed by the President of the Patent Office from the members members of the Patent Office for the individual case under dispu

(4) At the request of one of the parties the composition of th Arbitration has to be extended by one assessor from the circle of th and from the circle of the employees each. These assessors are the President of the Patent Office from proposal lists and designa single case under dispute. Those leading organisations named in § as trade unions and the independent employee associations with professional objectives, which are not connected with any of th organisations, if a substantial number of employees belong to t whom inventive achievements are to be expected in accordance duties in the company, are entitled to submit proposal lists.

(5) The President of the Patent Office shall select the assessor to paragraph 4 from the proposal list of the organisation to which concerned belongs if the party concerned has advised that he bel organisation prior to selection of the Board of Arbitration.

(6) The Board of Arbitration is under the supervision of the Cha Chairman under the supervision of the Federal Minister of Justice

§ 31 Appeal to the Board of Arbitration

(1) Appeal to the Board of Arbitration occurs by writter The request should be submitted in duplicate. It shall contai representation of the facts of the case as well as the name and addr other party concerned.

(2) The request is forwarded by the Chairman of the Board of A to the other party concerned with the invitation to express his com the request in writing within a specific period.

§ 32 Request to Extend the Board of Arbitration

The request to extend the Board of Arbitration must be submitte party appealing to the Board of Arbitration at the same time as th (§ 31 para. 1), by the other party within two weeks after receipt of th containing the appeal (§ 31 para. 2).

§ 33 Verfahren vor der Schiedsstelle

(1) Auf das Verfahren vor der Schiedsstelle sind § 1032 Abs. 1, §§ 1035 und 1036 der Zivilprozeßordnung sinngemäß anzuwenden. § 1034 Abs. 1 der Zivilprozeßordnung ist mit der Maßgabe sinngemäß anzuwenden, daß auch Patentanwälte und Erlaubnisscheininhaber (Artikel 3 des Zweiten Gesetzes zur Änderung und Überleitung von Vorschriften auf dem Gebiet des gewerblichen Rechtsschutzes vom 2. Juli 1949 – WiGBl. S. 179) sowie Verbandsvertreter im Sinne des § 11 des Arbeitsgerichtsgesetzes von der Schiedsstelle nicht zurückgewiesen werden dürfen.

(2) Im übrigen bestimmt die Schiedsstelle das Verfahren selbst.

§ 34 Einigungsvorschlag der Schiedsstelle

(1) Die Schiedsstelle faßt ihre Beschlüsse mit Stimmenmehrheit. § 196 Abs. 2 des Gerichtsverfassungsgesetzes ist anzuwenden.

(2) Die Schiedsstelle hat den Beteiligten einen Einigungsvorschlag zu machen. Der Einigungsvorschlag ist zu begründen und von sämtlichen Mitgliedern der Schiedsstelle zu unterschreiben. Auf die Möglichkeit des Widerspruchs und die Folgen bei Versäumung der Widerspruchsfrist ist in dem Einigungsvorschlag hinzuweisen. Der Einigungsvorschlag ist den Beteiligten zuzustellen.

(3) Der Einigungsvorschlag gilt als angenommen und eine dem Inhalt des Vorschlags entsprechende Vereinbarung als zustandegekommen, wenn nicht innerhalb eines Monats nach Zustellung des Vorschlages ein schriftlicher Widerspruch eines Beteiligten bei der Schiedsstelle eingeht.

(4) Ist einer der Beteiligten durch unabwendbaren Zufall verhindert worden, den Widerspruch rechtzeitig einzulegen, so ist er auf Antrag wieder in den vorigen Stand einzusetzen. Der Antrag muß innerhalb eines Monats nach Wegfall des Hindernisses schriftlich bei der Schiedsstelle eingereicht werden. Innerhalb dieser Frist ist der Widerspruch nachzuholen. Der Antrag muß den Tatsachen, auf die er gestützt wird, und die Mittel angeben, mit denen diese Tatsachen glaubhaft gemacht werden. Ein Jahr nach Zustellung des Einigungsvorschlages kann die Wiedereinsetzung nicht mehr beantragt und der Widerspruch nicht mehr nachgeholt werden.

(5) Über den Wiedereinsetzungsantrag entscheidet die Schiedsstelle. Gegen die Entscheidung der Schiedsstelle findet die sofortige Beschwerde nach den Vorschriften der Zivilprozeßordnung an das für den Sitz des Antragstellers zuständige Landgericht statt.

§ 33 Proceedings before the Board of Arbitration

(1) § 1032 para. 1, §§ 1035 and 1036 of the Code of Civil shall be applied mutatis mutandis to the proceedings before the Arbitration. § 1034 para. 1 of the Code of Civil Procedure shall mutatis mutandis subject to the condition that patent attorneys a of certificates of representation (Article 3 of the Second Law A Amendment and Transfer of Provisions in the Field of Legal Pr Industrial Property of 2 July 1949) as well as association repr within the meaning of § 11 of the Labour Courts Law must not l from the Board of Arbitration.

(2) Otherwise, the Board of Arbitration determines the p itself.

§ 34 Settlement Proposal of the Board of Arbitration

(1) The Board of Arbitration bases its decisions on majority v para. 2 of the Judiciary Act must be applied.

(2) The Board of Arbitration must put forward a proposal of to the parties concerned. The proposal of settlement must be sul and signed by all the members of the Board of Arbitration. The p settlement must indicate the possibility of opposition and the con of missing the opposition deadline. The proposal of settlement forwarded to the parties concerned.

(3) The proposal of settlement is regarded as having been acc an agreement corresponding to the content of the proposal as bein unless a written opposition is received by the Board of Arbitration of the parties concerned within one month from receipt of the pro

(4) If one of the parties concerned has been prevented from opposition within the set period by unavoidable circumstances, the be reinstated in the former position on request. The request mus in writing at the Board of Arbitration within one month of re the hindrance. Opposition must be made subsequently within th The request must specify the facts on which it is based and the r satisfactory proof of these facts. Reinstatement can no longer be and the opposition may no longer be effected one year after rece proposal of settlement.

(5) The Board of Arbitration decides the request for reins Immediate appeal to the Regional Court competent for the domici requesting party occurs against the decision of the Board of Arbi accordance with the provisions of the Code of Civil Procedure.

§ 35 Erfolglose Beendigung des Schiedsverfahrens

(1) Das Verfahren vor der Schiedsstelle ist erfolglos beendet,

1. wenn sich der andere Beteiligte innerhalb der ihm nach § 31 Abs. 2 gesetzten Frist nicht geäußert hat;
2. wenn er es abgelehnt hat, sich auf das Verfahren vor der Schiedsstelle einzulassen;
3. wenn innerhalb der Frist des § 34 Abs. 3 ein schriftlicher Widerspruch eines der Beteiligten bei der Schiedsstelle eingegangen ist.

(2) Der Vorsitzende der Schiedsstelle teilt die erfolglose Beendigung des Schiedsverfahrens den Beteiligten mit.

§ 36 Kosten des Schiedsverfahrens

Im Verfahren vor der Schiedsstelle werden keine Gebühren oder Auslagen erhoben.

6. Gerichtliches Verfahren

§ 37 Voraussetzungen für die Erhebung der Klage

(1) Rechte oder Rechtsverhältnisse, die in diesem Gesetz geregelt sind, können im Wege der Klage erst geltend gemacht werden, nachdem ein Verfahren vor der Schiedsstelle vorausgegangen ist.

(2) Dies gilt nicht,

1. wenn mit der Klage Rechte aus einer Vereinbarung (§§ 12, 19, 22, 34) geltend gemacht werden oder die Klage darauf gestützt wird, daß die Vereinbarung nicht rechtswirksam sei;
2. wenn seit der Anrufung der Schiedsstelle sechs Monate verstrichen sind;
3. wenn der Arbeitnehmer aus dem Betrieb des Arbeitgebers ausgeschieden ist;
4. wenn die Parteien vereinbart haben, von der Anrufung der Schiedsstelle abzusehen. Diese Vereinbarung kann erst getroffen werden, nachdem der Streitfall (§ 28) eingetreten ist. Sie bedarf der Schriftform.

(3) Einer Vereinbarung nach Absatz 2 Nr. 4 steht es gleich, wenn beide Parteien zur Hauptsache mündlich verhandelt haben, ohne geltend zu machen, daß die Schiedsstelle nicht angerufen worden ist.

(4) Der vorherigen Anrufung der Schiedsstelle bedarf es ferner nicht für Anträge auf Anordnung eines Arrestes oder einer einstweiligen Verfügung.

§ 35 Unsuc[illegible]ful Conclusion of Arbitration Proceedings

(1) The proceedings before the Board of Arbitration are [illegible] unsuccessfully:

1. if the other party concerned has not expressed his views [illegible] period set in accordance with § 31 para. 2;
2. if he has refused to enter the proceedings before the Arbitration;
3. if the Board of Arbitration has received a written opposition of the parties concerned within the period of § 34 para. 3,

(2) The Chairman of the Board of Arbitration advises of the uns conclusion of the arbitration proceedings to the parties concerned.

§ 36 Costs of the Arbitration Proceedings

No fees or expenses may be charged in the proceedings before t of Arbitration.

6. Judicial Proceedings

§ 37 Requirements for Filing an Action

(1) Rights or legal relationships regulated in this Act may only be with the action after proceedings before the Board of Arbitrat preceded it.

(2) This does not apply:

1. if rights from an agreement (§§ 12, 19, 22, 34) are being asse the action or the action is supported on the basis that the a does not have a legal effect;
2. if six months have passed since the appeal to the Board of Arbit
3. if the employee has departed the company of the employer;
4. if the parties have agreed not to appeal to the Board of Arl This agreement may only be made after the case under dispu has arisen. It must be in written form.

(3) It is equivalent to an agreement according to paragraph 2 No. parties have conducted oral proceedings on the substance of the case asserting that the Board of Arbitration was not appealed to.

(4) Moreover, prior appeal to the Board of Arbitration is not nece requests for ordering an arrest or an interim injunction.

(5) Die Klage ist nach Erlaß eines Arrestes oder einer einstweiligen Verfügung ohne die Beschränkung des Absatzes 1 zulässig, wenn der Partei nach den §§ 926, 936 der Zivilprozeßordnung eine Frist zur Erhebung der Klage bestimmt worden ist.

§ 38 Klage auf angemessene Vergütung

Besteht Streit über die Höhe der Vergütung, so kann die Klage auch auf Zahlung eines vom Gericht zu bestimmenden angemessenen Betrages gerichtet werden.

§ 39 Zuständigkeit

(1) Für alle Rechtsstreitigkeiten über Erfindungen eines Arbeitnehmers sind die für Patentstreitsachen zuständigen Gerichte (§ 143 des Patentgesetzes) ohne Rücksicht auf den Streitwert ausschließlich zuständig. Die Vorschriften über das Verfahren in Patentstreitsachen sind anzuwenden.

(2) Ausgenommen von der Regelung des Absatzes 1 sind Rechtsstreitigkeiten, die ausschließlich Ansprüche auf Leistung einer festgestellten oder festgesetzten Vergütung für eine Erfindung zum Gegenstand haben.

Dritter Abschnitt
Erfindungen und technische Verbesserungsvorschläge von Arbeitnehmern im öffentlichen Dienst, von Beamten und Soldaten

§ 40 Arbeitnehmer im öffentlichen Dienst

Auf Erfindungen und technische Verbesserungsvorschläge von Arbeitnehmern, die in Betrieben und Verwaltungen des Bundes, der Länder, der Gemeinden und sonstigen Körperschaften, Anstalten und Stiftungen des öffentlichen Rechts beschäftigt sind, sind die Vorschriften für Arbeitnehmer im privaten Dienst mit folgender Maßgabe anzuwenden:

1. An Stelle der Inanspruchnahme der Diensterfindung kann der Arbeitgeber eine angemessene Beteiligung an dem Ertrage der Diensterfindung in Anspruch nehmen, wenn dies vorher vereinbart worden ist. Über die Höhe der Beteiligung können im voraus bindende Abmachungen getroffen werden. Kommt eine Vereinbarung über die Höhe der Beteiligung nicht zustande, so hat der Arbeitgeber sie festzusetzen. § 12 Abs. 3 bis 6 ist entsprechend anzuwenden.

(5) The action is permissible after enactment of arrest or a injunction without the restriction of paragraph 1 if a period for action had been determined for the party in accordance with §§ 92 the Code of Civil Procedure.

§ 38 Action for Reasonable Remuneration

If there is dispute concerning the amount of remuneration, action may also be directed towards payment of a reasonable a be determined by the court.

§ 39 Jurisdiction

(1) The courts competent for patent litigations (§ 143 of the Pa are exclusively responsible for all cases of disputes concerning inve an employee without consideration of the value in dispute. The p concerning the procedure in patent litigation must be applied.

(2) Excepted from the ruling of paragraph 1 are those disputes w clusively relate to claims for payment of an established or fixed rem for an invention.

Third Section
Inventions and Technical Improvement Proposals of Employees Public Sector, Civil Servants and Members of the Armed Force

§ 40 Employees in the Public Sector

The provisions for employees in private employment should be to inventions and technical improvement proposals of employees er in Federal, regional or community companies and administrations ar corporations, institutes and foundations under public law status, su the following:

1. Instead of claiming the right to the service invention, the emplo claim a reasonable share of the income from the service inver this has been agreed beforehand. Binding agreements may be r advance concerning the extent of the share. If no agreement is r concerning the extent of the share, then the employer must fix para. 3 to 6 has to be applied mutatis mutandis.

2. Die Behandlung von technischen Verbesserungsv. ..chlägen nach § 20 Abs. 2 kann auch durch Dienstvereinbarung geregelt werden; Vorschriften, nach denen die Einigung über die Dienstvereinbarung durch die Entscheidung einer höheren Dienststelle oder einer dritten Stelle ersetzt werden kann, finden keine Anwendung.
3. Dem Arbeitnehmer können im öffentlichen Interesse durch allgemeine Anordnung der zuständigen obersten Dienstbehörde Beschränkungen hinsichtlich der Art der Verwertung der Diensterfindung auferlegt werden.
4. Zur Einreichung von Vorschlagslisten für Arbeitgeberbeisitzer (§ 30 Abs. 4) sind auch die Bundesregierung und die Landesregierungen berechtigt.
5. Soweit öffentliche Verwaltung eigene Schiedsstellen zur Beilegung von Streitigkeiten auf Grund dieses Gesetzes errichtet haben, finden die Vorschriften der §§ 29 bis 32 keine Anwendung.

§ 41 Beamte, Soldaten

Auf Erfindungen und technische Verbesserungsvorschläge von Beamten und Soldaten sind Vorschriften für Arbeitnehmer im öffentlichen Dienst entsprechend anzuwenden.

§ 42 Besondere Bestimmungen für Erfindungen von Hochschullehrern und Hochschulassistenten

(1) In Abweichung von den Vorschriften der §§ 40 und 41 sind Erfindungen von Professoren, Dozenten und wissenschaftlichen Assistenten bei den wissenschaftlichen Hochschulen, die von ihnen in dieser Eigenschaft gemacht werden, freie Erfindungen. Die Bestimmungen der §§ 18, 19 und 22 sind nicht anzuwenden.

(2) Hat der Dienstherr für Forschungsarbeiten, die zu der Erfindung geführt haben, besondere Mittel aufgewendet, so sind die in Absatz 1 genannten Personen verpflichtet, die Verwertung der Erfindung dem Dienstherrn schriftlich mitzuteilen und ihm auf Verlangen die Art der Verwendung und die Höhe des erzielten Entgelts anzugeben. Der Dienstherr ist berechtigt, innerhalb von drei Monaten nach Eingang der schriftlichen Mitteilung eine angemessene Beteiligung am Ertrage der Erfindung zu beanspruchen. Der Ertrag aus dieser Beteiligung darf die Höhe der aufgewendeten Mittel nicht übersteigen.

2. The han..ng of technical improvement proposals accordin para. 2 may also be regulated by employment agreement; p according to which a settlement by way of employment agree be replaced by the decision of a higher office or a third par apply.
3. In the public interest, the employee may be subject to re regarding the type of utilisation of the service invention by order of the competent highest authority.
4. The Federal and Regional Governments are also entitled to file lists for employer assessors (§ 30 para. 4).
5. If public authorities have set up their own boards of arbitra handling disputes on the basis of this Act, the provisions of 32 do not apply.

§ 41 Civil Servants, Members of the Armed Forces

The provisions for employees in the public sector should be applied mutandis to the inventions and technical improvement proposals servants and members of the Armed Forces.

§ 42 Special Provisions for Inventions of University Lecturers a University Assistants

(1) In departure from the provisions of §§ 40 and 41, the invent professors, lecturers and scientific assistants in scientific universities by them in this capacity are free inventions. The provisions of §§ 18, 22 do not apply.

(2) If the employer expended special means for research projects have led to the invention, then the persons named in paragraph 1 are to give written notice to the employer of exploitation of the invention specify on request the type of use and the amount of the proceeds re The employer is entitled to claim a reasonable share of the income invention within three months from receipt of the written notice. The i from this share must not exceed the extent of the expended means.

Vierter Abschnitt
Übergangs- und Schlußbestimmungen

§ 43 Erfindungen und technische Verbesserungsvorschläge vor Inkrafttreten des Gesetzes

(1) Die Vorschriften dieses Gesetzes sind mit dem Tage des Inkrafttretens dieses Gesetzes auch auf patentfähige Erfindungen von Arbeitnehmern, die nach dem 21. Juli 1942 und vor dem Inkrafttreten dieses Gesetzes gemacht worden sind, mit der Maßgabe anzuwenden, daß es für die Inanspruchnahme solcher Erfindungen bei den bisher geltenden Vorschriften verbleibt.

(2) Das gleiche gilt für patentfähige Erfindungen von Arbeitnehmern, die vor dem 22. Juli 1942 gemacht worden sind, wenn die Voraussetzungen des § 13 Abs. 1 Satz 2 der Durchführungsverordnung zur Verordnung über die Behandlung von Erfindungen von Gefolgschaftsmitliedern vom 20. März 1943 (Reichsgesetzbl. I S. 257) gegeben sind und die dort vorgesehene Erklärung über die unbefriedigende Behandlung der Vergütung im Zeitpunkt des Inkrafttretens dieses Gesetzes noch nicht abgegeben war. Für die Abgabe der Erklärung ist die Schiedsstelle (§ 29) zuständig. Die Erklärung kann nicht mehr abgegeben werden, wenn das auf die Erfindung erteilte Patent erloschen ist. Die Sätze 2 und 3 sind nicht anzuwenden, wenn der Anspruch auf angemessene Vergütung im Zeitpunkt des Inkrafttretens dieses Gesetzes bereits rechtshängig geworden ist.

(3) Auf nur gebrauchsmusterfähige Erfindungen, die nach dem 21. Juli 1942 und vor dem Inkrafttreten dieses Gesetzes gemacht worden sind, sind nur die Vorschriften über das Schiedsverfahren und das gerichtliche Verfahren (§§ 28 bis 39) anzuwenden. Im übrigen verbleibt es bei den bisher geltenden Vorschriften.

(4) Auf technische Verbesserungsvorschläge, deren Verwertung vor Inkrafttreten dieses Gesetzes begonnen hat, ist § 20 Abs. 1 nicht anzuwenden.

§ 44 Anhängige Verfahren

Für Verfahren, die im Zeitpunkt des Inkrafttretens dieses Gesetzes anhängig sind, bleiben die nach den bisher geltenden Vorschriften zuständigen Gerichte zuständig.

Fourth Section
Transitional and Final Provisions

§ 43 Inventions and Technical Improvement Proposals prior Act coming into Force

(1) As from the date of entry into force of this Act the pro this Act should also be applied to patentable inventions of employ were created after 21 July 1942 and prior to the entry into force c subject to the condition that the previously valid provisions still the claiming of right for such inventions.

(2) The same applies to patentable inventions of employees w created prior to 22 July 1942 if the preconditions of § 13 para. 1 2 of the implementing order for the Order for handling the inv staff members of 20 March 1943 (Reich Law Gazette I p. 257) and the declaration provided there concerning the unsatisfactory h remuneration at the time of entry into force of this Act had not yet b The Board of Arbitration (§ 29) is responsible for making the de The declaration can no longer be made if the patent granted to the has lapsed. Sentences 2 and 3 are not applicable if the claim for r remuneration was already pending at the time of entry into for Act.

(3) Only the provisions concerning arbitration proceedings a proceedings (§§ 28 to 39) are applicable to inventions only eligible model protection created after 21 July 1942 and prior to entry int this Act. Otherwise, the previously valid provisions remain applic

(4) § 20 para. 1 is not applicable to technical improvement prop utilisation of which began prior to entry into force of this Act.

§ 44 Pending Proceedings

For proceedings which are pending at the time of entry into for Act, the courts responsible in accordance with previously valid p remain competent.

§ 45 Durchführungsbestimmungen

Der Bundesminister der Justiz wird ermächtigt, im Einvernehmen mit dem Bundesminister für Arbeit die für die Erweiterung der Besetzung der Schiedsstelle (§ 30 Abs. 4 und 5) erforderlichen Durchführungsbestimmungen zu erlassen. Insbesondere kann er bestimmen,

1. welche persönlichen Voraussetzungen Personen erfüllen müssen, die als Beisitzer aus Kreisen der Arbeitgeber oder der Arbeitnehmer vorgeschlagen werden;
2. wie die auf Grund der Vorschlagslisten ausgewählten Beisitzer für ihre Tätigkeit zu entschädigen sind.

§ 46 Außerkrafttreten von Vorschriften

Mit dem Inkrafttreten dieses Gesetzes werden folgende Vorschriften aufgehoben, soweit sie nicht bereits außer Kraft getreten sind:

1. die Verordnung über die Behandlung von Erfindungen von Gefolgschaftsmitgliedern vom 12. Juli 1942 (Reichsgesetzbl. I S. 466)
2. Die Durchführungsverordnung zur Verordnung über die Behandlung von Erfindungen von Gefolgschaftsmitgliedern vom 20. März 1943 (Reichsgesetzbl. I S. 257).

§ 47 Besondere Bestimmungen für Berlin

(1) Dieses Gesetz gilt nach Maßgabe des § 13 Abs. 1 des Dritten Überleitungsgesetzes vom 4. Januar 1952 (Bundesgesetzbl. I S.1) auch im Land Berlin. Rechtsverordnungen, die auf Grund dieses Gesetzes erlassen werden, gelten im Land Berlin nach § 14 des Dritten Überleitungsgesetzes.

(2) Der Bundesminister der Justiz wird ermächtigt, eine weitere Schiedsstelle bei der Dienststelle Berlin des Patentamts zu errichten. Diese Schiedsstelle ist ausschließlich zuständig, wenn der Arbeitnehmer seinen Arbeitsplatz im Land Berlin hat; sie ist ferner zuständig, wenn der Arbeitnehmer seinen Arbeitsplatz in den Ländern Bremen, Hamburg oder Schleswig-Holstein oder in den Oberlandesgerichtsbezirken Braunschweig oder Celle des Landes Niedersachsen hat und bei der Anrufung der Schiedsstelle (§ 31) mit schriftlicher Zustimmung des anderen Beteiligten beantragt wird, das Schiedsverfahren vor der Schiedsstelle bei der Dienststelle Berlin des Patentamts durchzuführen.

(3) Der Präsident des Patentamts kann im Einvernehmen mit dem Senator für Justiz des Landes Berlin als Beisitzer gemäß § 30 Abs. 3 auch Beamte oder Angestellte des Landes Berlin berufen. Sie werden ehrenamtlich tätig.

§ 45 Impl enting Regulations

The Federal Minister of Justice is authorised to enact the in regulations necessary for extending the composition of the Arbitration (§ 30 para. 4 and 5) in agreement with the Federal Employment. He may determine in particular:

1. which personal conditions those persons must meet who proposed as assessors from circles of employers or employ
2. how the assessors selected on the basis of the proposal lis compensated for their activity.

§ 46 Annulment of Provisions

The following provisions shall be annulled on entry into force where they have not already been annulled:

1. the Order for handling inventions of staff members o 12 (Reich Law Gazette I p. 466);
2. the implementing order for the Order for handling inventio members of 20 March 1943 (Reich Law Gazette I p. 257).

§ 47 Special Regulations for Berlin

(1) This Act also applies to the Land of Berlin subject to § 13 the Third Transition Law of 4 January 1952 (Federal Law Gaz Legal orders enacted on the basis of this Act apply in the Land o accordance with § 14 of the Third Transition Law.

(2) The Federal Minister of Justice is authorised to set up a furth Arbitration at the Berlin office of the Patent Office. This Board of is solely responsible if the employee has his/her place of employr Land of Berlin; it is also responsible if the employee has his/he employment in the Land of Bremen, of Hamburg or Schleswig-H in the districts of the Federal Supreme Court of Braunschweig c the Land of Niedersachsen, and on appeal to the Board of Arbitra with the written agreement of the other participating party, is pe conduct the arbitration proceedings before the Board of Arbitrat Berlin office of the Patent Office.

(3) In agreement with the Senator of Justice of the Land of I President of the Patent Office may also appoint civil servants or e of the Land of Berlin as assessors in accordance with § 30 para. active without salary.

(4) Zu Beisitzern aus Kreisen der Arbeitgeber ‚d der Arbeitnehmer (§ 30 Abs. 4) sollen nur Personen bestellt werden, die im Land Berlin ihren Wohnsitz haben.

(5) Der Präsident des Patentamts kann die ihm zustehende Befugnis zur Berufung von Beisitzern auf den Leiter der Dienststelle Berlin des Patentamts übertragen.

§ 48 Saarland

Dieses Gesetz gilt nicht im Saarland.

§ 49 Inkrafttreten

Dieses Gesetz tritt am 1. Oktober 1957 in Kraft.

(4) Only rsons residing in the Land of Berlin should be a assessors from the circles of employers and employees (§ 30 pa

(5) The President of the Patent Office may transfer authority gr to appoint assessors to the Head of the Berlin office of the Pate

§ 48 Saarland

This Act does not apply in Saarland.

§ 49 Entry into Force

This Act enters into force on 1 October 1957.

EXHIBIT C

AUGUST 22, 2003, SALES AND TRANSFER AGREEMENT

DR. HANS VON GLEICHENSTEIN
IN HIS CAPACITY AS INSOLVENCY ADMINISTRATOR
OF THE ESTATE OF FAST TECHNOLOGIES AG

AND

MAGNA-LASTIC DEVICES, INC.

SALE AND TRANSFER AGREEMENT

FOR INTELLECTUAL PROPERTY RIGHTS
OF FAST TECHNOLOGIES AG

Contents

SALE and TRANSFER AGREEMENT

between

Dr. Hans von Gleichenstein in his capacity as insolvency administrator of the estate of FAST Technolgogy AG, Otto-Hahn-Strasse 24, Gewerbegebiet Riemerling, 85521 Ottobrunn, Germany

"Seller"

and

Magna-lastic Devices, Inc., 111 W. Buchanan Street, Carthage, IL 62321, United States of America

"Purchaser"

The Seller is insolvency administrator over the estate of FAST Technology AG ("**FAST AG**"), a stock corporation with its seat in Munich, Germany which was engaged, in particular, in the development and manufacture of non-contact sensors used to measure torque.

FAST AG has two subsidiaries, Fast Technology Limited with its seat in Newbury Berks, United Kingdom and FAST Technology L.L.C. with its seat in Livonia, Michigan (together the "**FAST Subsidiaries**").

The Purchaser, a subsidiary of Methode Electronics Inc., is also engaged in the field of torque sensing and control technology and is interested in gaining an undisputed prevailing ownership in the intellectual property rights which are relevant for its business.

Now, therefore, the Seller wishes to sell and the Purchaser wishes to purchase all IP Rights as defined below.

1. SALE AND TRANSFER

1.1 The Seller hereby sells and transfers to the Purchaser with effect as of 31 August 2003 (the "**Effective Date**") all patents, utility models, registered designs, trade marks, logos and know-how (in particular specific knowledge which has not yet been made available to the public) as well as similar intellectual property rights, whether registered or not, of FAST AG, together with all rights from applications for registration of such rights (together the "**IP Rights**"). In particular but without limitation thereto, the Seller sells and transfers to the Purchaser the IP Rights listed in Exhibit 1.1 whereby the sale and transfer of each of the IP

Rights under Nos. 21, 32 and 34 of the list titled "Summary of Cases" in Exhibit 1.1 (the "**IP List**") is subject to the dissolving condition (*auflösenden Bedingung*) that the respective Employee Inventor as defined in Clause 3.2 exercises his statutory pre-emption right (as set out in Clause 3 below). The Purchaser accepts this sale and transfer. To the extent that the transfer of legal title cannot be effected by the Effective Date, as between the parties, they shall put each other in a position they would have been in if the transfer had been effected by the Effective Date.

1.2 The IP Rights sold and transferred also include all inventions, business secrets, procedures, formulae and all technical know-how, exclusive and non-exclusive rights to use copy rights (*Nutzungsrechte*) including the right to use software developed in-house (for example by employees) (but excluding software licences from third parties), regardless of whether they are legally protected or not, including all their embodiments, such as for example drawings, records, including data available on files, other computer-readable media or other documentation relating to the IP Rights of FAST AG (all embodiments together the "**IP Documentation**").

1.3 In relation to the IP Rights sold and transferred under this Agreement, in particular those listed under Nos. 1, 2, 13, 30, 31 and 32 of the IP List, which are currently not yet owned by and/or not yet registered in the name of FAST AG, but for the transfer of which FAST AG has a legally valid claim against the respective inventors or any other third party (pursuant to contracts or otherwise), the Seller hereby sells and transfers these claims to the Purchaser. To the extent a sale and transfer of such claims is not legally possible, the Seller shall use all reasonable efforts to effect the legally valid registration of such rights for the Purchaser.

1.4 In relation to the IP Rights owned by FAST Subsidiaries, if any, the Seller will use its best efforts to procure that the FAST Subsidiaries transfer the relevant IP Rights to the Purchaser on or before 31 October 2003.

1.5 For the avoidance of doubt, the Parties agree that the sale and transfer of the IP Rights under this Agreement does not include the sale and transfer of any tangible assets (e.g. machines and equipment, technical facilities, trade and business fixtures, inventory) nor, with the exception of the IP Rights as defined and specified in Clauses 1.1 to 1.4 hereof, does it include the sale of any intangible assets; in particular, it does not include the sale and transfer of any customer relations or of contractual relationships of any kind such as supply, agency or lease agreements. Furthermore, the Parties agree that the sale and transfer of the IP Rights does not include the transfer of any employment relationship existing between FAST AG and any of its employees.

1.6 The Seller is obliged to give all declarations and perform all acts necessary to effect the change of registration of the IP Rights in the relevant registers to the Purchaser. A draft form

of such a consent declaration to the change of registration of the IP Rights is attached as Exhibit 1.6. The Purchaser shall submit to the Seller suitable assignment forms for each of the relevant registered IP Rights. The Seller shall present to the Purchaser the duly signed forms legalised by a public notary (with apostille affixed to the extent required by law) within 10 business days after receipt of the draft forms from the Purchaser.

1.7 As soon as possible following signature of this Agreement, the Seller shall submit to the Purchaser the IP Documentation. Furthermore, the Seller shall assist the Purchaser as much as reasonable possible, until the full transfer of title to the IP Rights will have been effected, to safeguard the protection of the IP Rights. In particular, the Seller will undertake all necessary steps to procure that all relevant applications for the prolongation of any IP Rights are made in due time.

2. PURCHASE PRICE

2.1 The purchase price amounts to EUR , subject to a purchase price reduction pursuant to Clause 3.3 (the "**Purchase Price**").

2.2 A partial purchase price of EUR (subject to Clauses 3.3 and 3.4 below) (the "**First Partial Purchase Price**") is due for payment to the Seller on the Effective Date.

2.3 A partial purchase price of EUR (subject to Clauses 3.3 and 3.4 below) (the "**Second Partial Purchase Price**") shall be due for payment to the Seller 10 business days after the last of the IP Rights listed in Exhibit 1.1, including in particular the IP Rights listed under Nos. 1, 2, 13, 30, 31 and 32 of the IP List have been legally valid registered in the name of the Purchaser, at the latest, however, on 1 September 2005.

2.4 Payments to the Seller shall be made to the following Seller's account:

Account Holder: Hans von Gleichenstein
Account No.: 7513104
Bank: Deutsche Bank
Sorting code: 700 700 24

Reference: "*Kaufpreis für IP-Rechte an Herrn von Gleichenstein in seiner Eigenschaft als Insolvenzverwalter der Fast Technologies AG*"

3. EMPLOYEE INVENTION (*ARBEITNEHMERERFINDUNG*) AND PURCHASE PRICE ADJUSTMENT

3.1 The Seller undertakes to procure that all employees who have made service inventions (*Diensterfindungen*) as defined in Section 4 Employee Inventors' Act (*Arbeitnehmererfindungsgesetz*) ("**AFG**") during the term of their employment with FAST AG, unless they have already done so, will duly notify the Seller of such inventions pursuant to Section 5 AFG prior to the Effective Date and the Seller will fully claim the rights under the inventions pursuant to Section 6 ss AFG. The Seller undertakes to use all reasonable efforts in order to procure that the legal assignment and registration of these rights for FAST AG and, ultimately, the Purchaser, is achieved without undue delay after signature of this Agreement.

3.2 The Purchaser is aware that the sold IP Right(s) listed under Nos. 21, 32 and 34 of the IP List are based on employees service inventions (*Diensterfindungen*) and are therefore subject to a statutory pre-emption right for the benefit of the respective employee inventor (the "**Employee Inventors**") pursuant to Section 27 para. 2 AFG to the effect that Georg Cuntze has a pre-emption right (*Vorkaufsrecht*) in respect of the IP Rights listed under Nos 21 and 32 of the IP List and David Kelly has a pre-emption right in respect of the IP Right listed under No. 34 of the IP List. The Seller undertakes to send a copy of this agreement to the Employee Inventors without undue delay after signature of this Agreement.

3.3 The Seller shall notify the Purchaser as soon as he has received notice from an Employee Inventor that he exercises his statutory pre-emption right. If such right is exercised, the Purchase Price is reduced by the purchase price payable by the Employee Inventor pursuant to Section 467 of the German Civil Code (the "**Purchase Price Reduction Amount**").

3.4 The Purchase Price Reduction Amount shall reduce the Second Partial Purchase Price. If the First Partial Purchase Price has already been paid to the Seller by the time the Purchase Price Reduction Amount becomes due, repayments thereof only become due if and to the extent the Purchase Price Reduction Amount exceeds the amount of the Second Partial Purchase Price.

4. REPRESENTATIONS AND WARRANTIES

4.1 The Purchaser has inspected the IP files available for FAST AG and compiled the information included in Exhibit 1.1. The Purchaser therefore has detailed knowledge about the IP Rights to be sold and their current legal status. The Seller does not give any representation or warranty in respect of the IP Rights, the IP Documentation or otherwise in respect of legal circumstances or effects described in this Agreement. In particular, the

Seller does not assume any liability for the existence of and ownership to the IP Rights listed in Exhibit 1.1.

4.2 Furthermore, all statutory warranty claims or other statutory or contractual claims for damages of the Purchaser out of or in connection with this Agreement, except for any claims which are based on gross negligence or wilful acts of the Seller, are excluded.

5. FUTURE BUSINESS - LICENSES

5.1 The Parties agree that, also after the sale and transfer of the IP Rights under this Agreement has become effective, the Seller may freely sell and transfer assets of FAST AG (other than the IP Rights and the IP Documentation sold and transferred to the Purchaser under this Agreement) to any third party, whether by selling and transferring individual assets or by transferring the whole business of FAST AG and that any such sale and transfer, even if this includes inventory which has been produced under exploitation of the IP Rights sold hereunder, shall in no event be construed as an infringement of the IP Rights.

5.2 Following the transfer of the IP Rights to the Purchaser as set out in this Agreement, in line with its business policy, the Purchaser will continue offering licenses for the use of its intellectual property rights including the IP Rights acquired hereunder under its standard terms and conditions. On that basis, the Purchaser is willing to enter into negotiations in view of a potential license of the IP Rights subject to such standard terms and conditions to qualifying former customers of FAST AG (in particular with Chicago Pneumatic Tool Company).

6. COSTS

All costs arising in connection with this Agreement, in particular all costs arising from the transfer of the IP Right to the Purchaser and the respective change of registration shall be borne by the Purchaser. For the avoidance of doubt, the Seller shall not bear any costs for the estate of FAST AG in connection with the fulfilment of his obligations pursuant to this Agreement, in particular in connection with his obligations pursuant to Clauses 1.6 and 1.7 hereof.

7. FINAL PROVISIONS

7.1 This Agreement contains all agreements reached between the Parties. There are no side agreements.

7.2 Any amendments or supplements to this Agreement as well as the waiver of any rights under this Agreement shall be in writing to be effective unless notarisation is required. This also applies to any amendment to, or cancellation of, this written form clause.

7.3 This Agreement is governed by German law. The place of exclusive jurisdiction for all disputes between the Parties arising out of or in connection with this Agreement or regarding its validity is Munich.

7.4 Should a provision of this Agreement or a provision included in this Agreement at a later point in time be or become invalid or null and void as a whole or in part, or should a gap in this Agreement become evident, this does not affect the validity of the remaining provisions. The invalid or null and void provision is replaced, or the gap is filled in, respectively, with effect *ex tunc* by such valid regulation which in legal and economic terms comes closest to what the Parties intended or would have intended in accordance with the purpose of this Agreement if they had considered the point at the time of conclusion of this Agreement.

22.8.03/
München, den 26.8.03 Chicago, IL 8-22-200
Place / Date Place / Date

For and on behalf of the Seller:

Name: Dr. v. Gleichenstein
Function: as Insolvency Administrator

For and on behalf of the Purchaser:

Name: DOUGLAS A. ICOMAN
Function VICE PRESIDENT CORPORATE FINANCE

GLEICHENSTEIN & BREITLING
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EXHIBIT 1.1
IP RIGHTS

SUMMARY OF CASES

(1.) TSIC, IC Patent, Electronics Patent, Torque Sensor IF (FT Case Ref:1)

US Patent No: 6,346,812
Assignees: Fast Technology GmbH & Fast Technology AG
Inventors: Lutz May, Adrian Paul Brokaw
Assignment from Adrian Paul Brokaw to Fast Technology GmbH recorded at USPTO on 16 February 2001;
Assignment from Lutz May to Fast Technology AG recorded at USPTO on 5 December 2001.

Japanese Patent Application No: 10-548920
Applicant: Lutz Axel May

European Patent No: 0981760
Patentee: Fast Technology AG
Validated in: Italy, Spain, Germany, Sweden, France and the United Kingdom
Assignment from original applicant Lutz May to Fast Technology AG recorded at EPO on 19 November 2001.

(2.) Torque/Force Base Patent (FT Case Ref:2)

US Patent Application No: 09/673930 US 6581480
Inventors/Applicants: Lutz May, Neil Brodey, John Owsley
Assignment from Lutz May to Fast Technology AG dated 12 February 2003, assignment from Neil Brodey to Fast Technology AG dated 21 March 2003; STILL AWAITING ASSIGNMENT FROM JOHN OWSLEY – Not received by Lloyd Wise as of 7 August 2003 despite numerous reminders both by telephone and facsimile/mail – No assignments yet recorded at USPTO.

Japanese Patent Application No: 2000-546211
Applicant: Fast Technology GmbH

European Patent Application No: 99907770.4
Applicant: Fast Technology AG

3. Automatic Gain Control (FT Case Ref: 3)

US Patent Application No: 09/937,230
Assignee: Fast Technology GmbH
Inventors: Lutz May, John Owsley
Assignment recorded at USPTO on 2 January 2003.

Japanese Patent Application No: 2000-606976
Applicant: Fast Technology AG

European Patent Application No: 00912776.2
Applicant: Fast Technology AG

Israeli Patent Application No: 145533
Applicant: Fast Technology AG

4. Torque and Speed Sensor (FT Case Ref: 4)

US Patent Application No: 09/937,638
Assignee: Fast Technology GmbH
Inventors: Lutz May, John Owsley
Assignment recorded at USPTO on 2 January 2002

Japanese Patent Application No: 2000-608152
Applicant: Fast Technology AG

European Patent Application No: 9907130.0
Applicant: Fast Technology AG

Israeli Patent Application No: 145534
Applicant: Fast Technology AG

5. Longitudinal (Toroid) L1 Disc (FT Case Ref:5)

US Patent Application No: 10/049,323
Assignee: Fast Technology AG
Inventor: Lutz May
Assignment recorded at USPTO on 14 May 2002.

Japanese Patent Application No: 2001-517133
Applicant: Fast Technology AG

European Patent Application No: 00953303.6
Applicant: Fast Technology AG

Israeli Patent Application No: 148017
Applicant: Fast Technology AG

5a. Disc Sensor (FT Case Ref:5a)

US Patent Application No: 10/049322
Assignee: Fast Technology AG
Inventors: Lutz May
Assignment recorded at USPTO on 14 May 2002.

Japanese Patent Application No: 2001-517134
Applicant: Fast Technology AG

European Patent Application No: 00853308.4
Applicant: Fast Technology AG

Israeli Patent Application No: 148016
Applicant: Fast Technology AG

6. Accelerometer (FT Case Ref:6)

US Patent Application No: 10/110,007
Assignee: Fast Technology AG
Inventors: Lutz May
Assignment recorded at USPTO on 14 May 2003.

Japanese Patent Application No: 2001-530597
Applicant: Fast Technology AG

European Patent Application No: 00971326.4
Applicant: Fast Technology AG

Israeli Patent Application No: 148957
Applicant: Fast Technology AG

7. Strong Ambient Field Sensor (FT Case Ref:7)

US Patent Application No: 10/089,978
Assignee: Fast Technology AG
Inventor: Lutz May
Assignment recorded at USPTO on 14 May 2002.

Japanese Patent Application No: 2001-530548
Applicant: Fast Technology AG

European Patent Application No: 00972736.3
Applicant: Fast Technology AG

Israeli Patent Application No: 148954
Applicant: Fast Technology AG

8. Load Cell, Physical Force Sensing, Pressure Sensor (FT Case Ref:8)

US Patent Application No: 10/239,545
Assignee: Fast Technology AG
Inventors: Lutz May
Assignment recorded at USPTO on 18 December 2002.

Japanese Patent Application No: 2001-571064
Applicant: Fast Technology AG

European Patent Application No:
Applicant: Fast Technology AG

Israeli Patent Application No: 151755
Applicant: Fast Technology AG

9. Longitudinal Process RS (1-2) (FT Case Ref:9)

US Patent Application No: 10/257,337
Assignee: Fast Technology AG
Inventors: Lutz May
Assignment recorded at USPTO on 11 February 2003.

Japanese Patent Application No: 2001-575421
Applicant: *Fast Technology AG*

European Patent Application No: 01931581.1
Applicant: Fast Technology AG

Israeli Patent Application No: 152178
Applicant: Fast Technology AG

10. (FT Case Ref:10)There are no active cases for this case, this being an investigation into a third party's patent some years ago.

11. Automatic Field Refresh Disc (FT Case Ref:11)

US Patent Application No: 10/258,275
Assignee: Fast Technology AG
Inventors: Lutz May
Assignment recorded at USPTO on 27 January 2003.

Japanese Patent Application No: 2001-586430
Applicant: Fast Technology AG

European Patent Application No: 01943403.4
Applicant: Fast Technology AG

Israeli Patent Application No: 152142
Applicant: Fast Technology AG

12. Axial Movement Compensating TS (FT Case Ref:12)

US Patent Application No: 10/297,980
Assignee: Fast Technology AG
Inventors: Lutz May
Assignment recorded at USPTO on 22 April 2003.

Japanese Patent Application No: 2002-510906

Applicant: Fast Technology AG

European Patent Application No: 01960281.2
Applicant: Fast Technology AG

Israeli Patent Application No: 153088
Applicant: Fast Technology AG

13. Hollow Shaft (FT Case Ref:13)

US Patent Application No: to be advised – awaiting official filing receipt
Inventor/Applicant: Lutz May
Assignment document from Lutz May to Fast Technology dated 21 March 2003 received by Lloyd Wise and forwarded to US attorney on 4 April 2003 – we are awaiting confirmation of recordal of the assignment from the USPTO.

Japanese Patent Application No: 2002-527746
Applicant: Fast Technology AG

European Patent Application No: 01952269.1
Applicant: Fast Technology AG

Israeli Patent Application No: 154855
Applicant: Fast Technology AG

14. Centre Magnet (FT Case Ref:14)

International Patent Application No: PCT/EP02/00786
Applicant: Fast Technology AG
Inventors: Lutz May

15. Portable Sensor Unit (FT Case Ref:15)
International Patent Application No: PCT/EP02/00784
Applicant: Fast Technology AG
Inventors: Lutz May

16. Axial Shift Measurement (FT Case Ref:16)

This case was cognated with the axial movement compensation TS case (case 12) as an international application – see case 12 above.

17. Angle Sensor (FT Case Ref:17)

International Patent Application No: PCT/EP01/13698
Applicant: Fast Technology AG
Inventors: Lutz May

18. Helical Coil – L1 Magnetisation (FT Case Ref:18)

International Patent Application No:PCT/EP02/01225
Applicant: Fast Technology AG
Inventors: Lutz May

19. Automatic Gain Control Compensation (FT Case Ref:19)

International Patent Application No:PCT/EP02/01704
Applicant: Fast Technology AG
Inventors: Lutz May

20. Maintenance Free High Precision Force Sensor (FT Case Ref:20)

International Patent Application No: PCT/EP02/01230
Applicant: Fast Technology AG
Inventors: Lutz May

21. Micro Coil Field Sensor (FT Case Ref:21)

International Patent Application No: PCT/EP02/08820
Applicant: Fast Technology AG
Inventors: Lutz May, Georg Cuntze

22. Plug Programmable Interface Unit (FT Case Ref:22)

International Patent Application No: PCT/EP02/04871
Applicant: Fast Technology AG
Inventors: Lutz May

(28) ~~23.~~ Impact Torque Measurement (FT Case Ref:23) 22030

International Patent Application No: PCT/EP0
Applicant: Fast Technology AG
Inventors: Lutz May

24. AC Disc Sensor – PM Magnetism (FT Case Ref:24)

International Patent Application No: PCT/EP02/06300
Applicant: Fast Technology AG
Inventors: Lutz May

25. Degaussing Unit (FT Case Ref:25)

This case has been abandoned.

26. Non-Encoded Sensor Host (FT Case Ref:26)

International Patent Application No: PCT/EP02/13952
Applicant: Fast Technology AG
Inventors: Lutz May

27. Torque Loss Measurement (FT Case Ref:27)

This case has been abandoned.

28. Improved Torque Pulse Processing (FT Case Ref:28)

The case has been abandoned.

29. Rotational Non-Uniformity Detection (FT Case Ref:29)

International Patent Application No: PCT/EP02/14520
Applicant: Fast Technology AG
Inventors: Lutz May

30. Pulse Torque Measurement APC (FT Case Ref:30)

International Patent Application No: PCT/EP03/01905
Applicant: Fast Technology AG
Inventors: Lutz May

US Patent Application No: to be advised – awaiting official filing receipt
Assignee: -
Inventors: Lutz May
Awaiting signed Assignment document from Lutz May – sent to Fast Technology for signature on 28 February 2003; document not received by Lloyd Wise as of 7 August 2003.

31. Linear Displacement Transducer (FT Case Ref:31)

International Patent Application No: PCT/EP03/01907
Applicant: Fast Technology AG
Inventors: Lutz May

US Patent Application No: 10/373,634
Assignee: -
Inventors: Lutz May
Awaiting signed Assignment document from Lutz May – sent to Fast Technology for signature on 28 February 2003; document not received by Lloyd Wise as of 7 August 2003.

32. Linear Position Sensor (FT Case Ref:32)

International Patent Application No: PCT/EP03/04355
Applicant: Fast Technology AG
Inventors: Lutz May; Georg Cuntze

US Patent Application No: 10/419,695
Assignee: -
Inventors: Lutz May; Georg Cuntze
Awaiting signed Assignment document from Lutz May and Georg Cuntze– sent to Fast Technology for signature on 25 April 2003; document not received by Lloyd Wise as of 7 August 2003.

33. Crossed Sensor Arrangement (FT Case Ref:33)

This case has yet to be filed.

34. Torque Sensor Adaptor (Goliath) (FT Case Ref:34)

British Patent Application No: 0219745.7
Applicant: Fast Technology AG
Inventors: Lutz May, David L Kelly

37. Wireless Torque Transducer (FT Case Ref:37)

British Patent Application No: 0222296.6
Applicant: Fast Technology AG
Inventors: unknown

38. (FT Case Ref:38)
This case was not handled by Lloyd Wise.

39. (FT Case Ref:39)

British Patent Application No: 0303841.1
Applicant: Fast Technology AG
Inventors: Unknown

LLOYD WISE
7 August 2003

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DECEMBER 06, 2001

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RECORDATION DATE: 12/05/2001

REEL/FRAME: 012213/0682
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL

DOC DATE: 11/08/2001

ASSIGNEE:
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SERIAL NUMBER: 09425888
PATENT NUMBER:

FILING DATE: 11/12/1999
ISSUE DATE:

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ASSIGNOR:
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DOC DATE: 11/08/2001

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SERIAL NUMBER: 09423888
PATENT NUMBER:

FILING DATE: 11/12/1999
ISSUE DATE:

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Chief Financial Officer and Chief Administrative Officer
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JANUARY 11, 2002

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RECORDATION DATE: 01/02/2002 — REEL/FRAME: 012293/0292
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL — DOC DATE: 11/08/2001

ASSIGNOR:
OWSLEY, JOHN — DOC DATE: 11/08/2001

ASSIGNEE:
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SERIAL NUMBER: 09937230 — FILING DATE:
PATENT NUMBER: — ISSUE DATE:

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RECORDATION DATE: 01/07/2002 REEL/FRAME: 012267/0328
NUMBER OF PAGES: 6

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL DOC DATE: 11/08/2001

ASSIGNOR:
OWSLEY, JOHN DOC DATE: 12/07/2001

ASSIGNEE:
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SERIAL NUMBER: 09937698 FILING DATE:
PATENT NUMBER: ISSUE DATE:

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RECORDATION DATE: 05/14/2002

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NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL

DOC DATE: 05/03/2002

ASSIGNEE:
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SERIAL NUMBER: 10049323
PATENT NUMBER:

FILING DATE:
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RECORDATION DATE: 05/14/2002

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BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
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DOC DATE: 05/03/2002

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SERIAL NUMBER: 10049322
PATENT NUMBER:

FILING DATE:
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RECORDATION DATE: 05/14/2002 REEL/FRAME: 012686/0687
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
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SERIAL NUMBER: 10110007 FILING DATE:
PATENT NUMBER: ISSUE DATE:

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RECORDATION DATE: 05/14/2002 REEL/FRAME: 012686/0681
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

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MAY, LUTZ AXEL DOC DATE: 05/03/2002

ASSIGNEE:
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SERIAL NUMBER: 10089978 FILING DATE:
PATENT NUMBER: ISSUE DATE:

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RECORDATION DATE: 12/18/2002 REEL/FRAME: 013306/0938
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL DOC DATE: 09/26/2002

ASSIGNEE:
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OTTO HAHN STR 24, GEWERBEGEBIET
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SERIAL NUMBER: 10239545 FILING DATE:
PATENT NUMBER: ISSUE DATE:

ALLYSON PURNELL, EXAMINER
ASSIGNMENT DIVISION
OFFICE OF PUBLIC RECORDS

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
ASSISTANT SECRETARY AND COMMISSIONER
OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

FEBRUARY 13, 2003

PTAS

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ROBERT C. KAIN, JR.
750 SOUTHEAST THIRD AVENUE
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UNITED STATES PATENT AND TRADEMARK OFFICE
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RECORDATION DATE: 02/11/2003 REEL/FRAME: 013424/0619
NUMBER OF PAGES: 4

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUIZ AXEL DOC DATE: 10/15/2002

ASSIGNEE:
FAST TECHNOLOGY AG
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GEWERBEGEBIET REIMERLING, D-85521
OTTOBRUNN, FED REP GERMANY

SERIAL NUMBER: 10257337 FILING DATE:
PATENT NUMBER: ISSUE DATE:

STEVEN POST, EXAMINER
ASSIGNMENT DIVISION
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Washington, D.C. 20231

JANUARY 28, 2003

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RECORDATION DATE: 01/27/2003

REEL/FRAME: 013385/0738
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL

DOC DATE: 10/15/2002

ASSIGNEE:
FAST TECHNOLOGY AG
OTTO HAHN STR 21
GEWERBEGEBIET RIEMERLING
D-85521 OTTOBRUNN, FED REP GERMANY

SERIAL NUMBER: 10250275
PATENT NUMBER:

FILING DATE:
ISSUE DATE:

SHARON BROOKS, EXAMINER
ASSIGNMENT DIVISION
OFFICE OF PUBLIC RECORDS

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
ASSISTANT SECRETARY AND COMMISSIONER
OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

APRIL 22, 2003

FTAS

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RECORDATION DATE: 04/22/2003 REEL/FRAME: 013587/0460
NUMBER OF PAGES: 3

BRIEF: ASSIGNMENT OF ASSIGNOR'S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
MAY, LUTZ AXEL DOC DATE: 12/04/2002

ASSIGNEE:
FAST TECHNOLOGY AG
OTTO HAHN STR 24
GEWERBEGEBIET RIEMERLING
D-85521 OTTOBRUNN, FED REP GERMANY

SERIAL NUMBER: 10297980 FILING DATE:
PATENT NUMBER: ISSUE DATE:

PAULA MCCRAY, EXAMINER
ASSIGNMENT DIVISION
OFFICE OF PUBLIC RECORDS

Internal Title: Torque IC
Official Titel: Conditioner Circuit for Torque Sensor

	[redacted]	[redacted]	[redacted]	US	FR
Case#Att.	56445	43505	44301	44302	44300
Appl. #	9709710.9	PCT/GB98/01357	10-548920	09/423,888	98 920 680.0-2214
filing date	13.05.1997	13.05.1998	13.05.1998	13.05.1998	13.05.1998
priority (file#)	-	GB 9709710.9	GB 9709710.9	GB 9709710.9	GB 9709710.9
priority date	-	13.05.1997	13.05.1997	13.05.1997	13.05.1997
publication #		WO 98/52063		US 6,346,812	EP 0 981 760
designated countries	-	all	-	-	AT, BE, CH, DE, FI, FR, GB, IT, NL, PT, SE
patent #		-		6,346,812	981760
date of grant		-		15.02.2002	20.03.2002
status	lapsed	ended	pending no request for examination filed yet, term for filing 13.05.2005	granted	granted
remarks				annual fees to be paid	annual fees to be paid
current actions	none	none	none	none	in force for Germany, France, Great Britain, Italy, Spain and Sweden

Internal Title: **Torque/Force**
Official Titel: Magnetising Arrangement for Torque/Force Sensor

	[redacted]			US	GB
Case#Att.	57159	43832	44838	44837	44836
Appl. #	9808792.7	PCT/GB99/00736	2000-546211	09/673,930	99907770.4
filing date	23.04.1998	11.03.1999	11.03.1999	11.03.1999	11.03.1999
priority (file#)	-	GB 9808792.7	GB 9808792.7	GB 9808792.7	GB 9808792.7
priority date	-	23.04.1998	23.04.1998	23.04.1998	23.04.1998
publication #		WO 99/56099			1070237
designated countries	-	all	-	-	AT, BE, CH, DE, ES, FI, FR, GB, IT, NL, PT, SE
patent #		-			
date of grant		-			
status	lapsed	ended	pending		pending
remarks		positive preliminary international examination report	request for examination has to be filed by 11.03.07	cost issue: 2000€ to be paid by 8th April 2003	
current actions	none	none	none	none	none

Internal Title: AGC
Official Title: Magnetised Torque Transducer Elements

	[redacted]					
Case#Att.	57571	44462	45500	45502	45499	45691
Appl. #	9906735.7	PCT/GB00/01103	2000-606976	09/937,230	00912776.2	145533
filing date	23.03.1999	23.03.2000	23.03.2000	23.03.2000	23.03.2000	23.03.2000
priority (file#)	-	GB 9906735.7	GB 9906735.7	GB 9906735.7	GB 9906735.7	GB 9906735.7
priority date	-	23.03.1999	23.03.1999	23.03.1999	23.03.1999	23.03.1999
publication #		WO 00/57150			1169627	
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	ended	pending	pending	pending	pending
remarks			request for examination has to be filed by 23.03.07			
current actions	none	none	none	none	none	none

Internal Title: Torque & Speed
Official Titel: Torque and Speed Sensor

	[redacted]	[redacted]	[redacted]	US	[redacted]	[redacted]
Case#Att.	57572	44463	45504	45506	45503	45505
Appl. #	9907130.0	PCT/GB00/01163	2000-608152	09/937,838	00912830.7	145534
filing date	26.03.1999	27.03.2000	27.03.2000	27.03.2000	27.03.2000	27.03.2000
priority (file#)	-	GB 9907130.0	GB 9907130.0	GB 9907130.0	GB 9907130.0	GB 9907130.0
priority date	-	26.03.1999	26.03.1999	26.03.1999	26.03.1999	26.03.1999
publication #		WO 00/58704			1166069	
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	ended	pending	pending	pending	pending
remarks			request for examination has to be filed by 27.03.07			
current actions	none	none	none	none	none	none

Internal Title: **Longitudinal Toroid.** Longitudinal Toroid. Disc Sensor
Official Titel: Longitudinally Magnetised Transducer (GB)
Magnetised Transducer Element for Torque or Force Sensor (PCT)

	[redacted]						
Case#Alt.	57859	44719	44720	45734	45729	45735	45730
Appl. #	9919065.4	PCT/GB00/03119	PCT/GB00/03125	2001-517133	2001-517134	10/049,323	10/049,322
filing date	12.08.1999	14.08.2000	14.08.2000	14.08.2000	14.08.2000	14.08.2000	14.08.2000
priority (file#)	-	GB 9919065.4	GB 9919065.4	GB 9919065.4	GB 9919065.4	GB 9919065.4	GB 9919065.4
priority date	-	12.08.1999	12.08.1999	12.08.1999	12.08.1999	12.08.1999	12.08.1999
publication #		WO 01/13081	WO 01/13082				
designated countries	-	all	all	-		-	
patent #		-	-				
date of grant		-	-				
status	pending?	pending	ended	pending request for examination has to be filed by 14.08.07	pending request for examination has to be filed by 14.08.07	pending	pending
remarks							
current actions	none	none	none	none	none	none	none

Applications named with *(1) belong to PCT(1), applications named with *(2) belong to PCT(2). The later are to be found in file internal #5a

[redacted]			
45732	45727	45733	45728
00953303.5	00953308.4	148017	148016
14.08.2000	14.08.2000	14.08.2000	14.08.2000
GB 9919065.4	GB 9919065.4	GB 9919065.4	GB 9919065.4
12.08.1999	12.08.1999	12.08.1999	12.08.1999
1203209	1203210		
pending	pending	pending	pending
none	none	none	none

Internal Title: **Accelerometer**
Official Title: Accelerometer

	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Case#Atl.	57721	44773	45836	45835	45834	45837
Appl. #	9923894.1	PCT/EP00/09783	2001-530597	10/110,007	00971326.4	148957
filing date	08.10.1999	05.10.2000	05.10.2000	05.10.2000	05.10.2000	05.10.2000
priority (file#)	-	GB 9923894.1	GB 9923894.1	GB 9923894.1	GB 9923894.1	GB 9923894.1
priority date	-	08.10.1999	08.10.1999	08.10.1999	08.10.1999	08.10.1999
publication #		WO 01/27638			1221055	
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	ended	pending	pending	pending	pending
remarks			request for examination has to be filed by 05.10.07			
current actions	none	none	none	none	none	none

Internal Title: **Torque Measurement**
Official Title: Torque Measurement Apparatus

	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Case#Att.	57722	44774	45840	45839	46838	45841
Appl. #	9924046.7	PCT/EP00/10022	2001-530548	10/089,978	00972736.3	148954
filing date	11.10.1999	10.10.2000	10.10.2000	10.10.2000	10.10.2000	10.10.2000
priority (file#)	-	GB 9924046.7	GB 9924046.7	GB 9924046.7	GB 9924046.7	GB 9924046.7
priority date	-	11.10.1999	11.10.1999	11.10.1999	11.10.1999	11.10.1999
publication #		WO 01/27584			1221030	
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	ended	pending	pending		pending
remarks		proceeded through preliminary examination	request for examination has to be filed by 10.10.07			
current actions	none	none	none	none	proceed to grant the patent!	none

Internal Title: **Physical Force Sensing**
Official Titel: Magnetic-based Force/Torque Sensing

	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Case#Alt.	57717	45196	46100	46089	↑	46101
Appl. #	0007532.5	PCT/EP01/03562	2001-571064	10/239,545		
filing date	28.03.2000	28.03.2001	28.03.2000	28.03.2000		28.03.2000
priority (file#)	-	GB 0007532.5				
priority date	-	28.03.2000				
publication #		WO 01/73390				
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	pending entry into national/regional phase by 28.09.2002				
remarks						
current actions	none	none			???	

Internal Title: **L2 Patent RS Process**
Official Titel: Magnetic Transducer Element and Method of Preparation

	England	PCT		US		
Case/Att.	57815	45209	46100		46158	46159
Appl. #	0009492.0	PCT/EP01/04077	2001-576421			152176
filing date	17.04.2000	10.04.2001	10.04.2001		10.04.2001	10.04.2001
priority (file#)	-	GB 0009492.0			01931581.1	
priority date	-	17.04.2000				
publication #		WO 01/79801				
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	pending entry into national/regional phase by 17.10.2002	ongoing	ongoing	ongoing	ongoing
remarks			regional phase	regional phase	regional phase	regional phase
current actions	none	none				

Internal Title:	**TRW-Joint Patent**
Official Title:	Power Steering Mechanism with Magnetoelastic Torsion Bar
	[redacted]
Case#Att.	J4189/4
Case#Teroti	TRW (M) 4278
Appl. #	09/516,382
filing date	29.02.2000
priority (file#)	-
priority date	-
publication #	US 6,360,841
designated countries	-
patent #	6,360,841
date of grant	26.03.2002
status	granted
remarks	joint application together with TRW
current actions	none

Internal Title: **Automatic Field Refresh**
Official Titel: Magnetic-based Torque/Speed Sensor

	[redacted]					
Case/Ait.	57834	45270	46138			46137
Appl. #	0012226.7	PCT/EP01/05705	2001-586430			
filing date	19.05.2000	17.05.2001	17.05.2001			17.05.2001
priority (file#)	-	GB 0012226.7				
priority date	-	19.05.2000				
publication #		WO 01/90711				
designated countries	-	all	-	-		
patent #		-				
date of grant		-				
status	lapsed	pending		proceeding	proceeding	proceeding
remarks		preliminary examination requested	since Dec 2002			
current actions	none	none				

Internal Title: **Axial Movement Compensated Torque**
Official Titel: Magnetic Transducer Torque Measurement

	[redacted]					
Case#Att.	57835	43297	46262	46254	46251	48253
Appl. #	0014568.0	PCT/EP01/06482	2002-510906	not yet known	01960281.2	153088
filing date	14.06.2000	07.06.2001		07.06.2001	07.06.2001	07.06.2001
priority (file#)	-	GB 0014568.0 GB 0025036.5				
priority date	-	14.06.2000 12.10.2000				
publication #		WO 01/96826				
designated countries	-	all	-	-		
patent #		-				
date of grant		-		11.Dec.2002		
status	lapsed	pending	proceeding national phase since Dec 02	proceeding national phase since Dec 02	proceeding national phase since Dec 02	proceeding national phase since Dec 02
remarks		preliminary examination requested	examination must be requested by 7th June 2008			
current actions	none	none				

Internal Title: **Torque Sensing Inside Shaft**
Official Titel: Magnetic Torque Sensor System

	[redacted]	
Case#/Ref.	57877	45477
Appl. #	0022315.6	PCT/EP01/10438
filing date	12.09.2000	11.09.2001
priority (file#)	-	GB 0022315.6
priority date	-	12.09.2000
publication #		WO 02/23146
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	pending
remarks		preliminary examination requested
current actions	none	none

Internal Title:	Centre Magnet	
Official Titel:	Magnetisation of Magnetic Transducer	
[redacted]		
Case#/AL	57887	15521
Appl. #	0101982.7	PCT/EP02/00788
filing date	25.01.2001	24.01.2002
priority (file#)	-	GB 0101982.7
priority date	-	25.01.2001
publication #		WO 02/059556
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	pending
remarks		preliminary examination requested
current actions	none	none

Internal Title:	**Portable Sensor Unit**	
Official Title:	Portable Magnetic Transducer	
	[redacted]	
Case#/Att.	57888	45530
Appl. #	0101981.9	PCT/EP02/00784
filing date	25.01.2001	24.01.2002
priority (file#)	-	GB 0101981.9
priority date	-	25.01.2001
publication #		WO 02/059555
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	pending
remarks		preliminary examination
current actions	none	none

Internal Title:	Axial Shift Measurement
Official Title:	Magnetic Transducer System
Case/Att.	57905
Appl. #	0025036.5
filing date	12.10.2000
priority (file#)	-
priority date	-
publication #	
designated countries	
patent #	
date of grant	
status	lapsed
remarks	
current actions	none

Priority of this GB-Application was claimed for PCT-Application internal#12 (Case# Att. 45297)

:Internal Title: **Magnetic Angle Sensor**
Official Titel: Angle Measurement by Magnetic Transducer

Case#Att	57922	45544
Appl. #	0028343.2	PCT/EP01/13698
filing date	21.11.2000	21.11.2001
priority (file#)	-	GB 0028343.2
priority date	-	21.11.2000
publication #		WO 02/42713
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	pending
remarks		search report issued
current actions	none	none

Internal Title:	Helical Coil L1 Mag.	
Official Title:	Longitudinally-Magnetised Transducer	
[redacted]		
Case/Att.	57936	45725
Appl. #	0103036.0	PCT/EP02/01225
filing date	07.02.2001	06.02.2002
priority (file#)	-	0103036.0
priority date	-	07.02.2001
publication #		WO 02/063262
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	pending
remarks		search report issued
current actions	none	none

Internal Title: **AGC Compensation**
Official Title: Magnetic Transducer Measurement

	[redacted]					
Case#Att	57957	45726				
Appl. #	0104409.8	PCT/EP02/01704				
filing date	22.02.2001	18.02.2002				
priority (file#)	-	GB 0104409.8				
priority date	-	22.02.2001				
publication #		WO01/27584				
designated countries	-	all				
patent #		-				
date of grant		-				
status	pending	pending				
remarks		search report issued	action on national phase to be taken by 22nd Aug 2003	action on national phase to be taken by 22nd Aug 2003	action on national phase to be taken by 22nd Aug 2003	action on national phase to be taken by 22nd Aug 2003
current actions	none	none				

Internal Title:	Barmag	
Official Title:	Measurement of Tension in Running Thread (GB) Force Sensor Device (PCT)	
Case#All	57972	45666
Appl. #	0103037.8	PCT/EP02/01230
filing date	07.02.2001	06.02.2002
priority (file#)	-	GB 0103037.8
priority date	-	07.02.2001
publication #		WO02/071018
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	pending
remarks		enter International preliminary examination until 07.09.02
current actions	none	none

Internal Title:	Micro Coil Field Sensor	
Official Title:	Magnetic Field Sensor	
	[redacted]	
Case#Att.	57985	46022
Appl. #	0119478.6	PCT/EP02/08820
filing date	09.08.2001	07.08.2001
priority (file#)	-	
priority date	-	
publication #		
designated countries	-	
patent #		
date of grant		
status	pending	
remarks		
current actions	decision about further applications claiming priority	

Internal Title:	**Plug Programmable Interface**					
Official Titel:	Data Transfer Protocol					
	[redacted]	[redacted]				
Case#Alt.	58016	45738				
Appl.#	0111482.6	PCT/EP02/04871				
filing date	10.05.2001	02.05.2002				
priority (file#)	-	GB 0111482.6				
priority date	-	10.05.2001				
publication #		WO 02/090891				
designated countries	-	all				
patent #		-				
date of grant		14. Nov 02	action on national phase to be taken by 10th Nov 2003	action on national phase to be taken by 10th Nov 2003	action on national phase to be taken by 10th Nov 2003	action on national phase to be taken by 10th Nov 2003
status	lapsed	pending				
remarks						
current actions	none	none				

Internal Title:	**Sensing and Measuring Torque of Impact Torque Tools**	
Official Titel:	Impact Torque Tool	
Case#Att.	58025	45881
Appl. #	0115494.7	
filing date	25.06.2001	
priority (file#)	-	GB 0115494.7-> AZ 23
priority date	-	25.07.2001->AZ 23
publication #		
designated countries	-	
patent #		
date of grant		
status	pending	
remarks		priority of this application was claimed together with priorities of Internal #27 and #28 for a single PCT-application see AZ 28
current actions	none	

Internal Title:	AC Disc Sensor	Pulse Modulated Magnetisation
Official Titel:	Disc Magnetic Torque Sensing	
	[redacted]	
Case#AZ	38028	45739
Appl. #	0114279.3	PCT/EP02/06300
filing date	12.06.2001	07.06.2002
priority (file#)	-	GB/0114279.3
priority date	-	12.06.2001
publication #		WO 02/101346
designated countries	-	all
patent #		-
date of grant		-
status	lapsed	publication on 19th Dec 2002
remarks		
current actions	none	none

Internal Title:	Degaussing Unit
Official Titel:	Degaussing Apparatus
Case#Att.	58029
Appl.#	[redacted]
filing date	15.11.2001
priority (file#)	-
priority date	-
publication #	
designated countries	-
patent #	
date of grant	
status	pending
remarks	PCT-application to be filed by 15 November 2002
current actions	none

Internal Title:	Non-encoded Sensor Hoist					
Official Title:	Magnetic Torque Transducer					
Case#Alt	58082	46270				
Appl. #	0129510.4					
filing date	10.12.2001					
priority (file#)	-					
priority date	-					
publication #						
designated countries	-					
patent #						
date of grant						
status	pending	proceeding	proceeding	proceeding	proceeding	proceeding
remarks						
current actions	none					

Internal Title:	Torque Loss Measurement	
Official Titel:	Torque Loss Measurement	
Case#Att.	58092	45861
Appl. #	0129509.6	
filing date	10.12.2001	
priority (file#)	-	GB 0129509.6
priority date	-	10.12.2001->AZ 27
publication #		
designated countries	-	
patent #		
date of grant		
status	pending	
remarks		priority of this application was claimed together with priorities of internal #23 and #28 for a single PCT-application see AZ 28
current actions	none	

Internal Title:	**Improved Torque Pulse Processing**	
Official Titel:	Power Torque Tool	
	[redacted]	
Case#Att.	58101	45881
Appl. #	0129511.2	PCT/EP02/06960
filing date	10.12.2001	24.06.2002
priority (file#)	-	GB 0129511.2
priority date	-	10.12.2001->AZ 28
publication #		
designated countries	-	
patent #		
date of grant		
status	pending	
remarks		see AZ 23/28!
current actions	none	

Internal Title:	**Rotational Non-Uniformity Detection**	
Official Titel:	Detecting Magnetic Rotational Non-uniformity	
	[redacted]	
Case#Alt.	58104	46284
Appl. #	0128382.6	
filing date	14.12.2001	13.12.2002
priority (file#)	-	
priority date	14.12.2001	
publication #		
designated countries	-	
patent #		
date of grant		
status	allowed to lapse	
remarks		
current actions	none	

Internal Title:	Pulsed Torque Measurement APC	
Official Title:	Pulsed Torque Measurement	
	[redacted]	
Case#Att.	58117	
Appl. #	0204213.3	
filing date	22.02.2002	
priority (file#)	-	
priority date	-	
publication #		
designated countries	-	
patent #		
date of grant		
status	pending	proceed further til 22.Feb 2003!
remarks		
current actions		*advised Jan 24.03*

Internal Title:	**Linear Displacement Transducer**
Official Titel:	Magnetic-Based Transducer For Measuring Displacement
	[redacted]
Case#Att.	58129
Appl. #	02055341.1
filing date	08.03.2002
priority (file#)	-
priority date	08.03.2002
publication #	
designated countries	-
patent #	
date of grant	
status	pending
remarks	
current actions	***become a PCT*** ***act until 8. March 2003*** ***advised Jan 24.03***

Internal Title:	**Linear Position Sensor**
Official Titel:	Magnetic Displacement Sensor
	[redacted]
Case#Att.	58141
Appl. #	0209240.1
filing date	23.04.2002
priority (file#)	-
priority date	23.04.2002
publication #	
designated countries	
patent #	
date of grant	
status	pending
remarks	
current actions	***become a PCT?*** ***act until 23.04.2003*** ***advised Jan 24.03***

Internal Title:	Crossed Sensor Arrangement
Official Title:	
Case#/Alt	58148
Appl. #	
filing date	?
priority (file#)	-
priority date	-
publication #	
designated countries	-
patent #	
date of grant	
status	in preparation
remarks	
current actions	none

Internal Title:	**Torqun Sensor Adaptor (Goliath)**
Official Titel:	Torque Sensor Adaptor (Goliath)
[redacted]	
Case#A#	58179
Appl. #	0219745.7
filing date	23.08.2002
priority (file#)	-
priority date	-
publication #	
designated countries	
patent #	
date of grant	
status	filed
remarks	
current actions	none

Internal Title: Torque and Angle Measurement
Official Title:

[redacted]

~~Case#/Atl.~~	
Appl. #	
filing date	
priority (file#)	-
priority date	-
publication #	
designated countries	-
patent #	
date of grant	
status	In preparation
remarks	
current actions	

Internal Title: non-contact torque and linear position sensing
Official Title:

Case#/Att.	[redacted]
Appl. #	
filing date	
priority (file#)	-
priority date	-
publication #	
designated countries	-
patent #	
date of grant	
status	in preparation
remarks	
current actions	

Internal Title:	non-contact, electrical power producing torque transducer for pulse tool applications
Official Titel:	
Case#Att	58195
Appl. #	0222296.6
filing date	25.09.2002
priority (file#)	-
priority date	
publication #	
designated countries	
patent #	
date of grant	
status	In preparation
remarks	
current actions	

Internal No. (AZ)	Patent Matter	FAST Name	Filing Date	Case ID	PCT	Appl Number	EP	USA	
29	Detecting Magnetic Retentional Non-Uniformity	Rotational Non-Uniformity Detection, RSU Detection	14/12/2001	58104	48284	0128982.5			
30	Pulsed Torque Measurement	Pulsed torque Measurement APC	22/02/2002	58117	48788	0204213.3			
31	Pulsed Torque Measurement	Linear Displacement Transducer	08/03/2002	58129	49401	0205934.1			
32	Magnetic Displacement Sensor	Linear Position Sensor	23/04/2002	58197 58141	48902	0209240.1			
33		Crossed Sensor Arrangement		58148					
34	Torque Sensor Adaptor	Target Sensor Adapter (Delete)	23/09/2002	58179		0219745.7			
35		Torque and Angle Measurement							
36		non-contact torque and linear position sensing							
37		non-contact , electrical power producing torque transducer for power tool applications	25/09/2002			0222198.6			
38		Signal Processing & Control for a Power Torque Tool	18/12/2002	03185/EP					
39	Measuring the weight of a load	Measuring the weight of a load	19/03/2003	58244		0303841.1			
40		Shaft magnetisation processing							
41		Combined torque/angle sensor		58176					
42		Torque rate control		58174					
43		Torque/force measurement on tool bit		58175					
44		Drift free torque measurement		58178					
				58166					

zu diesen Anmeldungen haben wir keine detaillierten Angaben.

Kurz